PRODUCT ENGINEERING

MARCH, 1942

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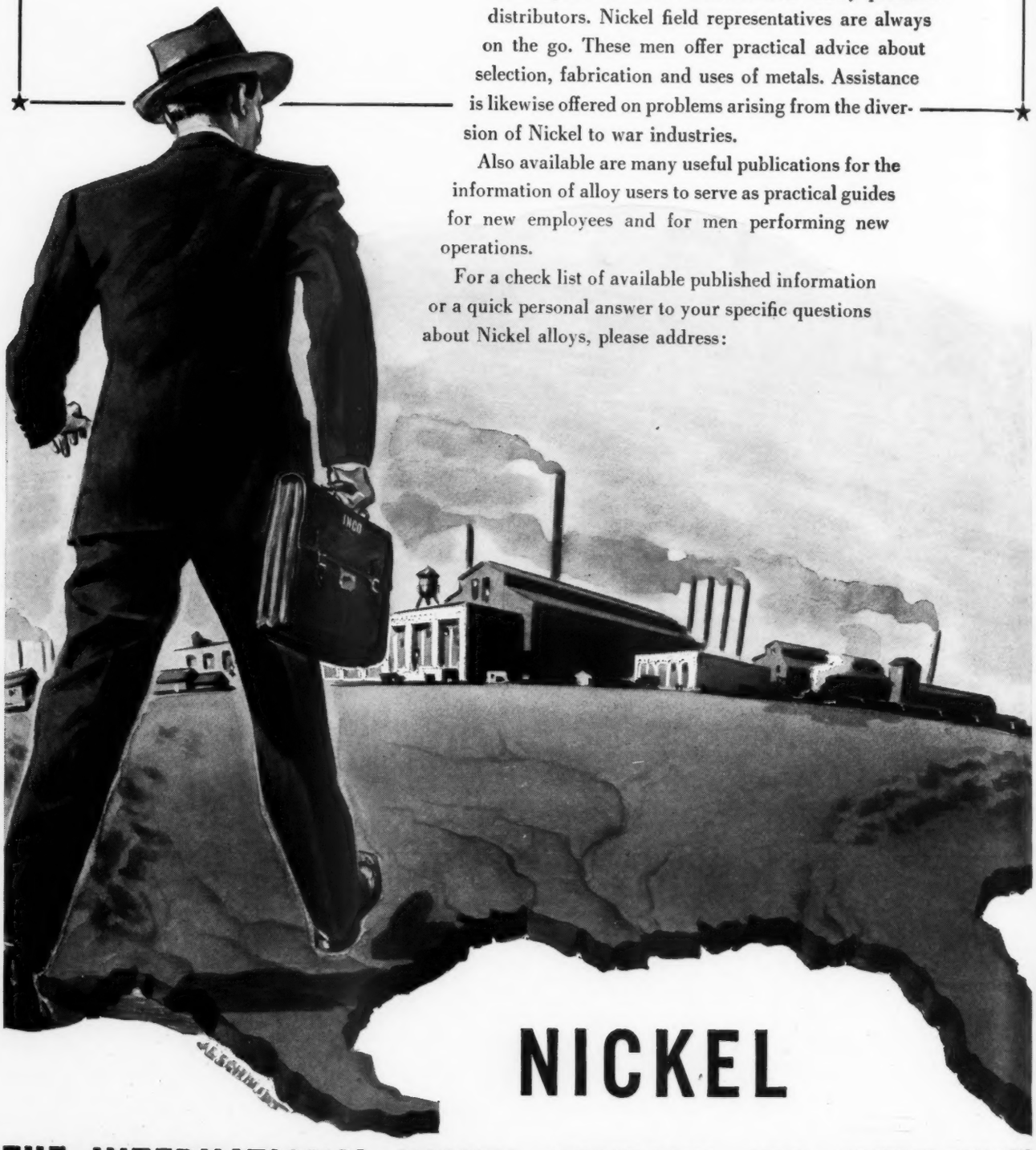

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PRODUCT ENGINEERING

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PRODUCT ENGINEERING

VOLUME XIII MARCH, 1942 NUMBER 3

IN THIS ISSUE

Hydraulic Cylinders

The design of hydraulic actuating cylinders not only involves estimation of proper bore and stroke, weight, and space required, but also involves much juggling of usable design details such as types of attachments, packings and adjustment facilities, in order to obtain the required stroke without exceeding maximum permissible lengths or weights. Feature article for this month begins a series which sets forth these problems met in designing hydraulic cylinders. Collaborating authors James E. Thompson and Rodney B. Campbell base their article on experiences gained from two different aircraft companies. And hydraulic actuating cylinders for aircraft are undoubtedly the most exacting of any hydraulic equipment.

Big

A giant forging machine, weighing more than 500,000 lb. but nonetheless compact and accurate, wins lead position among this month's Modern Designs. Accuracy is achieved by massive cast steel bed frame, heavy alloy steel tie-bars, and unique slide bearing design. This latter also accounts for its compactness. Other features are its mammoth air-cooled clutch and automatic relief toggles. Details on pages 128 to 130. Designed and built by National Machinery Company, this "biggest-of-its-kind" machine is now forging aircraft engine cylinders.

Synthetic Resin Varnish

Special tests developed by two Westinghouse engineers, L. E. Frost of the research department and Graham Lee Moses, insulation engineer, have shown that a thermosetting synthetic resin varnish has excellent qualities for insulating windings on heavy duty electric motors. Aside from its dielectric strength, the researchers report, the varnish fills interstices in windings,

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providing shock-resistant, dust-proof construction essential for railway, truck and industrial motors. For properties of the varnish and results of tests, see pages 144 to 146 of this issue.

Selenium Rectifiers

Dry plate rectifiers have been a valuable aid to the designer of electrical power and control equipment. Selenium rectifiers are the newest of the dry plate type. In this country, with selenium available in almost unlimited quantities, production got off to a late start in 1938—but now is "going places." Their characteristics and uses should be of interest to you. See page 135 of this issue for the first of a series of articles on the subject by C. A. Clarke.

Automatic Oilers

Oilcups are available which do much more than flood a bearing with oil. Some can be regulated to exact bearing needs, can be shut off when the machine is not running, and even have filters when required. Use of these oilers means less of the operator's time spent in babying the bearings, and more of his time spent in pushing production. On pages 142 and 143 of this issue there are sketched a dozen and a half different types of automatic oilers —one to fit every need.

Patent Procedure

Anybody can make out a patent application, but he may be wasting his time and money. The wise inventor finds out ahead of time how good a chance his application has of being granted. Miles Henninger, in this month's issue, explains the "why" and "how" of preliminary investigations. Begins on page 148.

Materials Data

O.P.M.'s worries about chromium have resulted in a committee report on ways to substitute for the strategic metal. Condensed for PRODUCT ENGINEERING readers on pages 157 and 158.

Felt, commonly classed as a textile, is considered on pages 159 and 160 as its manufacturers regard it—a three-dimensional engineering material having definite qualifications for numerous mechanical applications such as vibration dampeners, insulators, grease retainers.

Plate glass has many possibilities in product engineering, we conclude after skimming through the article beginning on page 161. Strengths achieved are somewhat better than most designers realize, we believe, and the many methods for machining and finishing the material may astound you.

Perbunan, an improvement over earlier type of Buna rubber, is said to be more like natural rubber than any other synthetic rubber. There will be a lot of it made in this country some day soon, we hope. Get acquainted with its properties; pages 163 and 164 in this issue.

Cork, an imported product, will not be available for all applications. See pages 165 for alternate materials for low-temperature insulation, classified by properties and qualifications.

Data on common high brass, pages 166-168, are continuations of the Wilkins-Bunn series presenting graphical pictures of the physical properties of various brass analyses.

Acceleration-Sensitive Governors

A governor that wouldn't hunt, no matter what you did with it or with the controls, would be an engineer's dream. Anti-hunting features can make ordinary centrifugal governors nearly perfect at the expense of considerable complication, but simple combinations of inertia and centrifugal governors can come nearest to the ideal—close control of speed with no hunting. Some of the theory involved and some concrete examples are shown on pages 150 to 153 in this issue.

Wrenches—Give 'Em Room

If the designer of a piping layout guesses at how much space is necessary for wrench clearance, the chances are he will either allot too much valuable space, or will locate the bolt so close to walls or columns that special tools will have to be made to reach the nuts in the tight spots. In an article which eliminates this guesswork, Arthur K. Horn describes advantages in using offset wrenches, and presents tables of clearances required by 45-deg. offset wrenches and by double offsets of 45 and 80 deg. when bolting up standard pipe flanges. Handy reference: page 154.

How Efficient Is a Worm Gear?

After you have designed a worm and gear set, if you want a quick computation of its efficiency, turn to this month's Reference Book Sheet, page 179. There A. C. Rasmussen presents convenient data sheets for computing efficiencies, complete with tables of trigonometric functions and radian measures especially worked out for the problem.

WHAT'S COMING

Designs for Materials Conservation

The growing vastness of the Victory Program has made the question of materials of tremendous strategic importance and has given birth to delayed deliveries and priorities. These have thrust the product engineer into a chaos of change, and have imposed upon him many difficult problems.

We label this problem "materials conservation." It embraces elimination of difficult-to-obtain materials, simplification of design so that less strategic material is used, and improving designs so that less scrap is produced. Aim is to release all strategic material possible so that it can be made available for more urgent defense needs.

PRODUCT ENGINEERING next month will publish a big special section aimed squarely at this problem. Typical designs collected from all types of industries will show in detail many materials-conserving design changes that have been made and tested. The subjects of alternate materials, design simplification, and design changes to reduce scrap will each be covered in a separate section. More than 60 pages will be devoted to designs for materials conservation, presented in a manner to be of greatest help to the product engineer.

Present value: To show how to achieve, in the face of materials shortages, the faster production now urgently needed through new uses for new materials, new uses for old materials, and better designs requiring less materials. Most of the design changes presented will represent equally good or improved quality.

Present and future value: The collection of ideas in the big special issue will point to new materials and more efficient design techniques which might be incorporated in designs for the future.

Where-to-Buy Directory

April PRODUCT ENGINEERING will include the annual "Where-to-Buy Directory." Edited specifically for product engineers, this directory will carry more than 300 listings of materials, electrical and mechanical parts and finishes. A separate division covers engineering and drafting room equipment. Well worth saving, it will come in handy whether you're buying priority or non-priority materials.

"Ten Silver Months . . ."

"EVERY WEAPON *we make today is worth ten that we might produce next year; for this year – 1942 – is the critical year in the existence of the United States.*"

This grim challenge was thrown at American industry by Donald Nelson in his first speech as chief of the War Production Board. He was speaking to a group of business paper editors, called together to receive at first hand Mr. Nelson's urgent message to the industries they serve.

"We've wasted the golden months", he declared, "the months in which we could have expanded our steel industry, our chemical industry, our copper industry, and all the others, so that we would have plenty of everything. But we still have ten silver months – the months that remain in 1942–and in them we can do things that we never thought possible."

To that objective Mr. Nelson has dedicated his high talents and boundless energy. And to that task he asks American industry to apply the full measure of its resources and skill.

That challenge should be all that it takes to exact from industry the last ounce of its energies. For by now we all can see that in this war the American way of life is at stake. American industry is the essence of the American way of life. Neither can survive without the other. So, even if it had no better reason, industry must go all out to win this war as a measure of self-preservation. Here self-interest and patriotic duty are synonymous. American industry cannot afford to let America lose this war.

The 1942 job is crucial. If it is well done we have a chance to win. If it is badly done we cannot possibly win. There is the measure of the responsibility that now rests upon the shoulders of industrial management.

It is not just Donald Nelson who asks this of industry. He speaks for the millions of fighting men – on land, at sea, in the air – the world over, whose eyes turn so desperately to the workshops of America. There and there alone can they see the hope of victory.

The people of America are not going to let those men down. They demand of industry every effort and every sacrifice that may be necessary to back them up. On that score, American industry stands, of necessity, on trial before our people. It must come through – or else!

* * *

As industry goes all out to meet this demand, its management asks of those who set its tasks and supervise its performance the utmost possible cooperation. It asks of them specifically an understanding of its problems and a chance to work them out without unnecessary interference. It asks for protection against attack from the rear while it concentrates its energies against the common foe. It asks a truce on economic reforms and social experiments that have nothing to do with winning the war and that are bound to arouse misgiving and mistrust amongst the proprietors of industry. Above all, it asks that it be not made a political scapegoat for every deficiency that is sure to develop in the confusion of a war effort.

This does not mean that industry resents honest criticism or constructive direction. Neither does it mean that it is unwilling to do its best unless it can have its own way in all things. The managers of industry are practical men. They know better than anyone else that unprecedented conditions call for new methods, that they must be open-minded to every criticism sincerely directed toward winning the victory. They know that no one can afford to be smug in the face of a national crisis.

There would be no point to my rehearsing here the pros and cons of such criticisms. Time is too short for that. Only in its performance can industry write a convincing answer to its critics. But as a help toward the achievement of that performance, I should like to clear up, if I can, one prolific source of misunderstanding and mistrust.

I refer to the solicitude of industrial managers as to where their companies may find themselves after the war. *This concern for the future sometimes is misinterpreted to mean that management is blind to the urgency of the present. But it does not mean that. It is a perfectly natural anxiety that must be felt by any responsible management operating under the American enterprise system – which is one of the things we are fighting to preserve.*

Under our system, the managers of industry cannot but feel a sense of responsibility to its owners, not merely for current dividends on their investments but also for the conservation of their properties. That means they must feel some concern over what may happen after the war to a business that now must go all out to help win the war. And their concern is but part of a general concern over what may be the effect of the war on the whole American way of life, preservation of which is our reason for being at war.

To give practical effect to that concern under present conditions is one of the problems of management. It is not an insuperable problem. Competent management will be able to surmount it, I am sure. But the right kind of help from those in authority can make the job a lot easier. And let us note in passing that the problem cannot be written off, as some critics of business seem to think, merely by setting off against it the profits that business can make on war contracts. That misses the whole point.

For a business enterprise is not, as many seem to think, just a "profit-machine." It is not set up and operated by its owners and managers for the sake of this month's or this year's profits, without regard to any other consideration.

The fact is that any worth-while business must operate as a going concern. It consists not only of stockholders and managers, but also of employees, markets, distributors, and dealers. Mostly, I might say, of markets, distributors, and dealers. They are the "reason for being" of any business, the source of its payrolls and its profits.

No competent management wants to scrap such essential elements of its business just for the sake of war-bred profits, however large they might look . . . at the moment. Most of the original reluctance to get into arms production, for which industry has been criticized, was not due to a "greed for profits", as has been charged. Rather did it arise from management's mistrust of "war profits" that can be made only by sacrificing the essential elements of a healthy business.

* * *

But now industry faces a dire national emergency. The survival of our country and all its institutions – including American business–is at stake. So management must shape its course to meet without stint every need of the war

effort. That means it must subordinate to that effort every other concern. To lose the war is to lose all. We must first win the war if we would save anything.

To the men of management that presents a grave responsibility. It is fair to ask whether government can do anything to help them meet it. One simple thing I think government can and should do. It cannot dissolve all the concerns of management, but it can help substantially.

Government should do all it can to help management conserve those assets of business that will contribute to post-war reconstruction, when that can be done without prejudice to getting on with the war.

Let me explain. Broadly speaking, every business comprises three elements. One is its tangible assets — its factories, machinery, equipment, and materials. Another is its productive capacity — its management, organization, trained working force. A third is its intangible assets — the goodwill, familiarity, acceptance, and recognition that it enjoys amongst its dealers, customers, and prospective customers.

When the nation goes to war government becomes the one dominant customer of a business. Of these three elements, the first two — plant facilities and organization — become of paramount importance to the job in hand. But so far as the government buyer is concerned, the third drops to minor importance.

But that third element cannot be ignored by the managers responsible for that business. For it will be their mainstay when they must rebuild that business after the war, when government has lost all interest in its existence, except as a source of tax revenue. That is why government can help greatly if now, during the war, it recognizes the legitimate concern of management to conserve those assets that will be essential to survival after the war.

Everyone recognizes the obligation of government to demand that the individual business go all out for war production, to forbid the production of goods not essential to wage war and to commandeer those that are, to require that a business sacrifice its markets and disrupt its distribution organization. No one questions the right of government to restrict arbitrarily the amount of earnings that a business may retain as profit from its war activities. In short, no one questions the right of government to become the dominant partner in any business that may be needed to win the war and, as dominant partner, to put the national need above any conflicting interest of the business.

But, as it does all this, government should remember that the survival of that business is staked on the public's knowledge and use of those discontinued or commandeered products, on the stability of that crippled dealer organization, on the ability of the business to maintain its standing in a market-place from which, temporarily, it may be barred.

And government can help management to deal with the exacting task it now faces, if it will do all it can to avert the needless sacrifice of business interests that do not conflict with war needs, if it will but remember that one of these days, that business again will be on its own, gathering up whatever resources it may have left, recreating its markets, rebuilding its distribution channels, reestablishing itself as a going concern . . . and doing all this in a competitive world without benefit of war orders.

The only foundation upon which any business can hope to rebuild when that day comes is its customers' memory of its name and their understanding of its products. Whatever credit may be coming to it for its war effort will not avail it very much if it permits itself to be forgotten. Its chief assets in that day will be the identity, recognition, and acceptance it still enjoys amongst those to whom it must look for business.

That is why so many business men, already going all out on their war jobs, become apprehensive whenever some word or act of a legislator or government official seems to question the validity of their sales, promotion, and advertising activities during the war. For they know that it is by such measures alone that any management can hope to conserve — while its business goes to war — the values it will need when it returns to civilian service.

That is why I ask government to do all it can to allay such uncertainties, to reassure business of its desire to help conserve those intangible assets that mean so much to business security. For that, I believe, will strengthen the hand of management in a big way as it goes all out on the vital job Donald Nelson has staked out for industry.

* * *

He has told us that if we are to make these ten silver months productive enough to make up for the golden months that are gone, industry must do things it never thought it could do. That is dead right. For America now finds itself in a position it never thought it could be in.

All too slowly, but very surely, it is dawning upon us that this is OUR WAR. Moreover it was our war long before we knew it or did much about it. So our job today is not merely to match the current production of our enemies. That is not enough. We must produce also enough to match the surplus of resources they had built up before we got started. We must produce enough not only for our own needs, but also for all the United Nations.

Moreover we must produce all that we need for decisive victory, for anything short of that will mean defeat. If we would save the American way of life, we must destroy once and for all the forces that threaten it. A stalemate would mean but an armed truce and what that might do to the American way of life and to American industry no one dares to guess. Victory must mean *decisive* victory. And this, very definitely is our war.

And just as definitely, this is OUR YEAR. For in this year — 1942 — we must prevent our enemies from achieving an advantage that might put victory forever beyond our reach — despite all our vast resources. It is an appalling fact that victory may slip beyond our grasp — not in 1943 or in 1944 — but during the months just ahead of us.

"Industry's responsibility in all of this is great," says Donald Nelson. "The job will take brains and initiative, but we can do it if we go out with a will."

To Mr. Nelson, that initiative means that industry must lead rather than follow in the march to more intensive use of our machines and our man-power. We dare not wait for new facilities to meet our mounting needs. More and more we must press for more widespread subcontracting and conversion. And he is counting on that initiative, backed by ever more aggressive effort, to avert or to minimize the compulsory measures that now seem imminent.

"We must stop thinking about what we're going to do to the enemy in 1943 and start thinking of what we're going to do to him in March of 1942.We must make today the things we would be making next year . . . if we had the time to spare."

That, says Donald Nelson, is the task of American industry during the next "Ten Silver Months." And to that gigantic task American industry now must bend every ounce of its abundant strength.

James H. McGraw, Jr.

President, McGraw-Hill Publishing Company, Inc.

This message is appearing in all McGraw-Hill industrial and business publications, reaching over a million readers.

PRODUCT ENGINEERING

GEORGE F. NORDENHOLT, *Editor*

Vision and Enterprise

"Young men shall see visions and old men shall dream dreams."

While men dreamed that their fortifications would be impregnable, that their battleships would be unsinkable, and that marshy jungles would serve as impenetrable protection, young men saw visions. The visions crystalized into plans and the plans were put to test. When the moment to strike arrived, the army marched around the fortifications and captured them from the rear with little sacrifice of men; torpedo planes and bombers sank the battleships; and armored tanks crushed the jungle growth into roadways over which the army marched and captured the citadel.

The Alps were supposedly impassable, but Hannibal went over them. The cliffs at Quebec presumably could not be scaled, but Wolfe went up them and defeated Montcalm who had been lulled into a sense of security. The British were caught napping at Trenton because they imagined that Washington could not cross the Delaware. Innumerable similar episodes come to mind. And in almost every instance the reward for vision, initiative and enterprise was victory.

Dreaming has never won a contest nor has it ever solved a problem. It is defined as effortless thinking. The dreamer simply brushes aside facts and possibilities that dispute his contentions and conclusions. "I couldn't have imagined that such a thing could ever happen," is a confession that the speaker has never explored the possibilities and given them serious thought. Or such an exclamation might indicate a mind that has grown old.

It will require boundless vision and enterprise to win this war. Vision and enterprise will be essential not only in the strategical conduct of the war, but also in all our civilian attitudes and activities and in the operation of the engineering departments that are developing the designs of our fighting equipment and essential civilian goods. In wrestling with the innumerable engineering problems which must be solved, designers are facing repeatedly situations for which there seem to be no solution. Dreaming of what might be done if materials that are unobtainable were available, contributes nothing to solving the problem. Progress cannot begin until the problem has been stripped of all its non-essentials. Traditions, preconceived notions, age old conceptions, competitive considerations and similar ideas must be cast aside.

With the design problem stripped to its basic fundamentals, the solution resolves itself into a study of the materials that might be used, especially those developed more recently; a search of the mechanical, electrical or hydraulic devices that might suit; an investigation of the coatings that might be applied to give desired surface properties; an analysis of types of constructions, manufacturing processes and numerous other possibilities.

Even the simplest problem requires a methodical analysis as the first step. But method alone will not give the answer. Vision and enterprise must be brought to bear on the problem in order to obtain outstanding results.

Today the all-important problem is how to conserve materials. Design engineers have the greatest share in the solution of this problem and they are attacking it with great vision and enterprise. Through the use of "substitute" materials and design changes, they are making more out of less. Exactly how they are doing it is a story of value and interest to all design engineers. For three months the editors of PRODUCT ENGINEERING have been calling on engineering executives to get the facts. And in our April number the story will be told in line drawings, pictures, captions and tables; a story that portrays in part at least, the vision and enterprise of the design engineers of America.

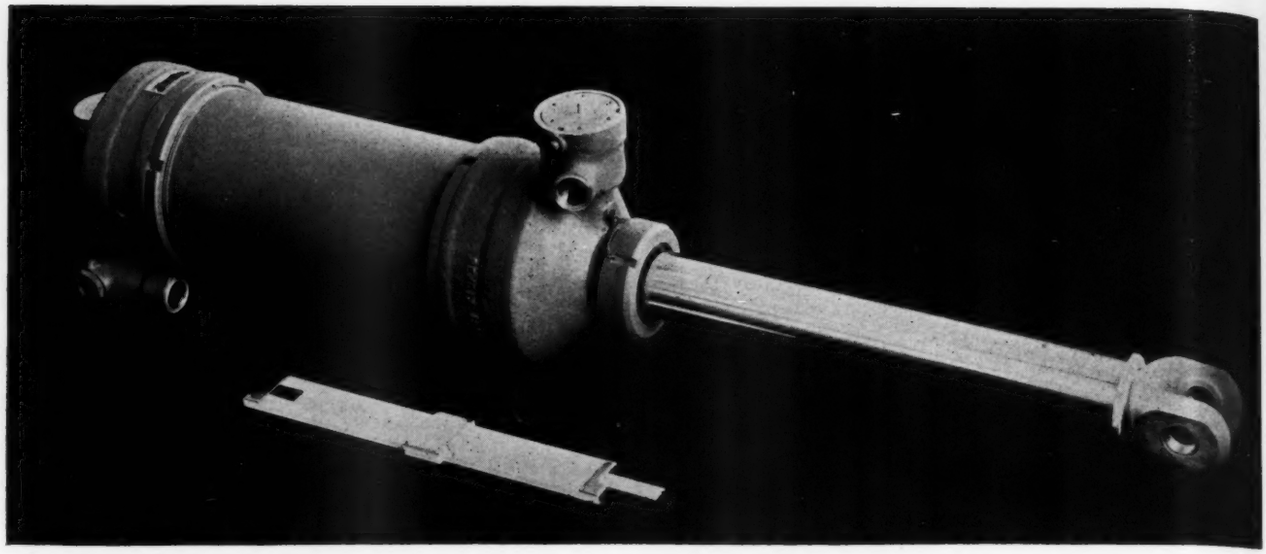


Fig. 1—Actuating cylinder with a 5½-in. bore, the thrust on the piston rod is 60,000 lb. at test pressure

HYDRAULIC CYLINDERS – I

JAMES E. THOMPSON and RODNEY B. CAMPBELL

THERE ARE two basic designs for hydraulic actuating cylinders: one wherein the end-caps are threaded to the cylinder barrel and another wherein tension-studs or stay-rods are used to clamp the barrel between the end-caps. The former design is preferable and is the only design considered here. It has the advantage of: (1) using smaller diameter end-caps; (2) weighing less, owing to elimination of stay-rods and their end-cap bosses; (3) simplification of machining by elimination of the rabbeted joint inclosing the gasket of a cylinder using stay-rods; and 4) elimination of leakage resulting from unequal tightening of the rods.

When stay-rods are used to clamp the end-caps to the barrel, it is necessary to provide sufficient rods to prevent deflection of the end-caps, and resultant gasket failure. In no case should less than three rods be used, and four are preferable, particularly when the maximum working pressure exceeds 500 lb. per sq. in. The rods must be of ample diameter, have sufficient threads in engagement to resist the maximum shear loads, and be designed for pre-loading equal to the maximum load imposed by the working pressure, in order to avoid loosening of the gaskets from elongation of the rods under load.

Logical analysis of the problems involved will permit any qualified engineer to apply the basic design principles of hydraulic cylinders to any modification of the cylinder designs described because it will be found that a majority of the design modifications encountered will involve only the end connections and mounting provisions of the cylinder, with the internal working parts remaining substantially the same.

Preliminary Design

The hydraulic engineer frequently encounters the problem of determining a basic system in the preliminary design or proposal stage. At this time the principal requirements are the system's basic circuit, and determination of estimated dimensions and weights for the actuating cylinders involved. This will permit the designers engaged in rough-ing-out the basic structural design to provide space for plumbing and cylinders, and to complete an estimated weight schedule for the complete structure when necessary.

Once the bore and stroke required for a cylinder are known, it is possible to estimate accurately both its dimensions and weight. The bore is governed by the force required and the available hydraulic working pressure at the cylinder. The hydraulic working pressure

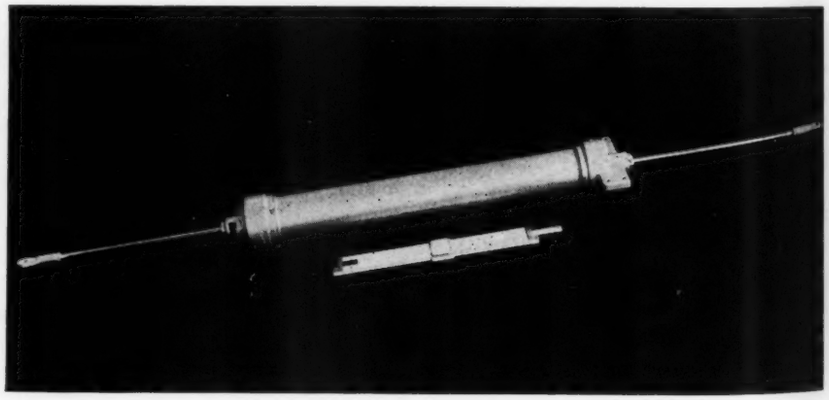


Fig. 2—Double-acting cylinder with two piston rods

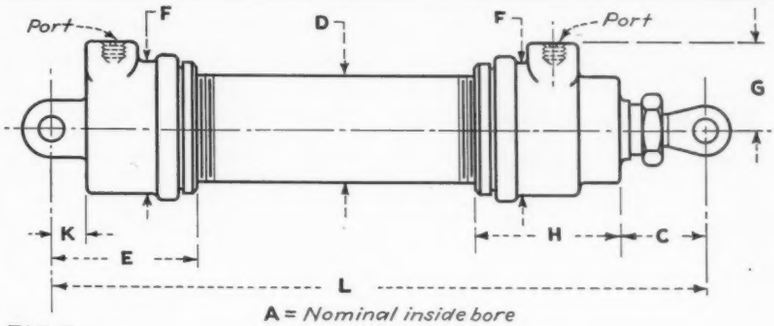
available at the cylinder is always less than the normal system working pressure, as developed by the power-driven pump and maintained by the pressure regulator, due to line restrictions and friction. It is unwise to assume that more than 80 percent of the normal system pressure will be delivered to the actuating cylinders. Otherwise the cylinders selected may be undersize and a difficult job of installing cylinders larger than the structure actually provides for will ensue.

Cylinder Bore Calculations

The cylinder bore required is determined on the basis of the force required during both extension and retraction of the cylinder. The maximum force will be developed by the cylinder during extension. Therefore, the movement of the mechanism which imposes the greatest load should be planned for operation by extension of the cylinder. The piston rod area, as governed by the column and bending loads imposed, should then be determined and the force developed during retraction of the cylinder calculated. This will be less than that developed during extension by an amount equal to the piston rod area times unit operating pressure. If this is found to be insufficient for the load imposed by the mechanism being operated, the cylinder's bore must be increased sufficiently to provide adequate effective area on the piston-rod end of the piston. This will also provide excess area on the piston-head and consequently a force during extension in excess of actual requirements, but usually this is not objectionable.

Required Stroke

The basic stroke required is governed by the geometry of the mechanism, and the design stroke should always be 3/8 in. greater, to provide for adjustment, deflection of attaching structure,



A = Nominal inside bore
S = Stroke

FIG.5

Code	A = From 1.0 to 2.0 in.	A = From 2.0 to 3.0 in.	A = From 3.0 to 4.0 in.
C	1 3/8" min.	1 9/16" min.	1 7/8" min.
D	A + 1/8"	A + 3/16"	A + 1/4"
E	2 1/2" min.	2 7/8" min.	3 1/4" min.
F	A + 9/16"	A + 1/16"	A + 7/8"
G	A/2 + 5/8"	A/2 + 3/4"	A/2 + 7/8"
H	2 7/8" min.	3 1/4" min.	3 1/2" min.
K	5/8"	3/4"	1"
L	S + 5"	S + 5 3/4"	S + 6 1/2"

Fig. 5—Actuating cylinder dimension chart

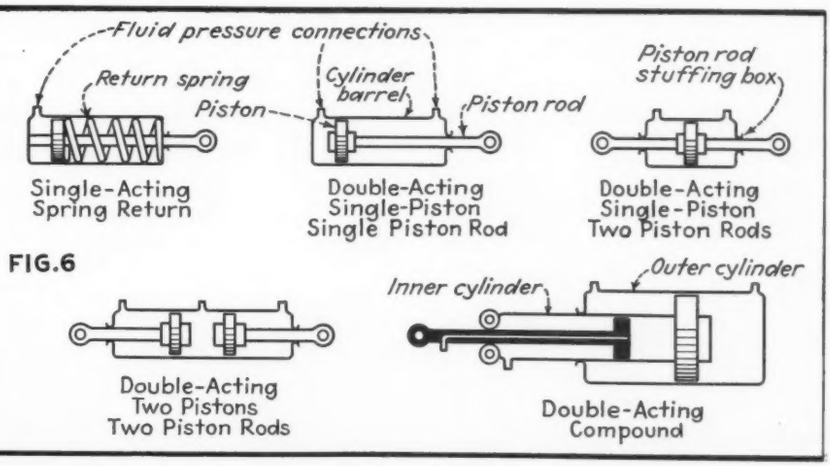


FIG.6

Fig. 6—Types of actuating cylinders

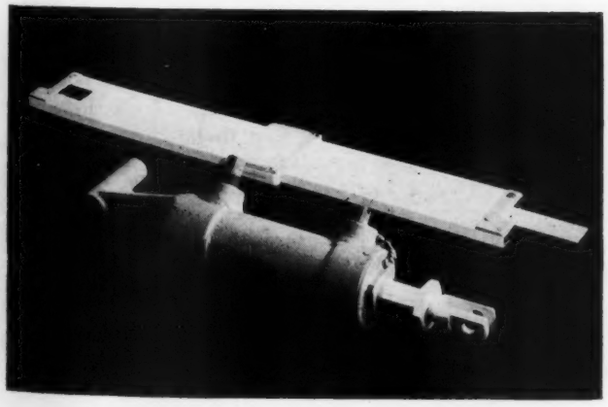


Fig. 3—Small double-acting actuating cylinder

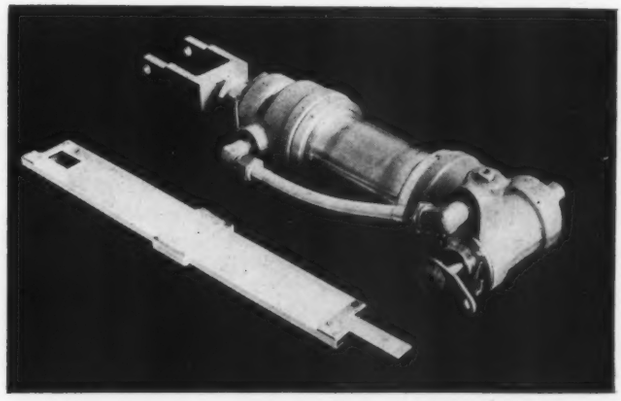


Fig. 4—Double-acting actuating cylinder with swivel joint

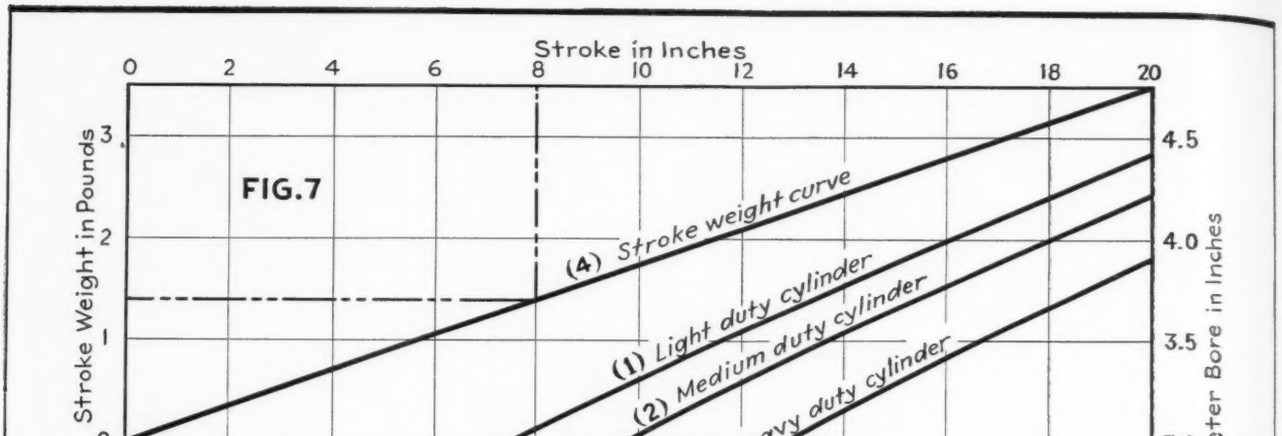

Stroke in Inches
0 2 4 6 8 10 12 14 16 18 20
FIG.7
Stroke Weight in Pounds
0 1 2 3
(4) Stroke weight curve
(1) Light duty cylinder
(2) Medium duty cylinder
(3) Heavy duty cylinder
EXPLANATION
2¾" dia. x 8 stroke medium duty cylinder weights 6.4 lb.
Thus:
Basic weight = 5 lb.
Stroke weight = 1.4 lb. / 6.4 lb.
Nominal Inside Diameter Bore in Inches
1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5
1 2 3 4 5 6 7 8 9 10 11
Basic Weight in Pounds

Fig. 7—Actuating cylinder weight estimation chart

and lost motion in the mechanism being operated. Once the bore and stroke are known, it is possible to estimate accurately the overall dimensions of a conventional double-acting cylinder by reference to the formulas shown in Fig. 5. These are based upon average dimensions taken from a large number of actuating cylinders, and permit accurate dimensional estimates.

Eliminating the Weight

With bore and stroke known, next is the problem of estimating the weight of each of the actuating cylinders. This can be done by reference to Fig. 7, from which it is possible to obtain, with proper interpretation, weights accurate to plus or minus 5 percent for cylinders up to 4 in. bore and 20 in. stroke. The data are strictly empirical and are based upon information gathered from dozens of actuating cylinders of all sizes and types.

To use the chart, Fig. 7, select the proper bore and trace across the chart until the proper type-curve is intersected and then read down to find the basic weight. Then find the intersection of the cylinder's stroke and curve (4), and read across for the weight increase due to stroke. The sum of basic and stroke weights is the estimated weight.

Three type curves are shown in the chart: (1) for light-duty cylinders up to 3 in. bore, (2) for medium-duty cylinders up to and including 4 in. bore, and (3) for heavy-duty cylinders up to and including 4 in. bore.

Light-duty cylinders are usually constructed with cast or forged aluminum-alloy end-caps, thin steel or aluminum-alloy barrel, and a light steel or aluminum-alloy piston connected to a tubular piston rod fitted with a plain rod-end. Medium-duty cylinders use heavy end-caps, steel barrel, heavy bronze or steel piston, and a heavy-wall piston rod fitted with a heavy-duty antifriction rod-end. Heavy-duty cylinders generally employ steel and bronze construction throughout and are equipped with swivel joints, dashpots, or stroke stops.

The data given in Fig. 7 are applicable only to conventional designs, and do not provide allowances for such special features as integral locks, special mounting brackets, or extended piston rods. Such additional features must have their weights calculated and added to the estimated weight obtained from the chart.

Space Allowances

It must be made certain that sufficient space is allowed for the actuating cylinders when designing the structure, and there is no use in deluding one's self that satisfactory cylinders can be designed to fit within cramped quarters. The dimensions given in Fig. 5 are the minimum practical dimensions for serviceable, economical cylinders. Although it is possible to design cylinders having slightly smaller overall dimensions, it is certain that these will be expensive to manufacture, difficult to install and likely to be continual sources of maintenance difficulties.

To insure that adequate space is allowed for the hydraulic cylinders and their plumbing, it is necessary that the preliminary design of the hydraulic system be developed simultaneously with the structural design, and in close collaboration with the engineers engaged with the structural problems. While it

is necessary to make many compromises throughout the design, it is also necessary that none of these compromises be permitted to affect the functional efficiency or manufacturing economy of the hydraulic system and its components.

Detail Design

The detail design of an actuating cylinder can be begun once the basic piston and piston-rod diameters are known, the required design stroke determined and the maximum permissible retracted length ascertained. The general procedure involves laying out the locations of the attachment points at piston head, end-cap and piston rod for both extended and compressed lengths, drawing a center line through these three points and locating the lines indicating the cylinder I.D. on each side of this center line. This seems like a simple procedure; actually it is for it marks only the start of the job. The real job involves the juggling of usable designs for the various components in order to obtain the required stroke without exceeding the maximum permissible retracted length.

A typical double-acting actuating cylinder of simple design is shown in Fig. 8, and this will be used for the basis of our discussion of actuating cylinder design. The design of a cylinder similar to this should begin by establishing the reference points previously listed and then roughing out designs for both of the end-caps, piston, and the piston rod end fitting.

Once these components are established, it is possible to determine the actual overall length of the fully retracted cylinder. This value will be the sum of the following dimensions:

(A) Distance from cylinder head end-cap attachment axis to piston head stop.

(B) Stroke.

(C) Piston overall length.

(D) Piston rod packing gland overall length.

(E) Allowance for piston rod end fitting.

These dimensions and their relationship are clearly shown in Fig. 8. It will be readily apparent that the only method of reducing the cylinder's retracted length is by shortening the dimensions (A), (C), (D) or (E), as the stroke (B) remains constant.

The distance between cylinder head end-cap attachment axis and the piston head stop is governed by the nature of the attachment fitting and the consequent clearance required for its connection, and by the cylinder head thickness necessary to withstand the working pressure. Another consideration influencing both cylinder head thickness and the attaching lug or clevis dimensions is the necessity of having the end-cap sufficiently rigid to avoid measureable deflection at maximum applied load. Should a measurable deflection occur, it may damage the pivot bearing, particularly if needle bearings are used.

Overall piston length is governed largely by the necessity of providing ample piston packing, piston bearing area, and positive means of adjusting the piston packing. Experience has shown that not less than three chevron-type packings are necessary at each end of the piston. Although a single chevron will seal perfectly under ideal conditions, it is necessary to have three packings to provide a reasonable margin of safety under adverse conditions. Inadequate piston bearing area will result in rapid piston wear and frequent replacement of piston packing, as the load normally carried by the piston bearing area will then be transferred to the packing and packing gland parts. Adequate means of adjusting the piston packing must be provided if maximum packing life is to be expected. This requires a piston length sufficient to provide a reasonable adjustment range for the packing nut or nuts.

The overall length of the piston rod packing gland is governed by the cylinder head wall thickness, packing necessary to seal properly the piston rod, and the adjustment provided. Three chevrons are the minimum which will insure an adequate pressure seal for the piston rod, and it is sometimes desirable to use another chevron, faced in the opposite direction, as a wiper for the piston rod. This type of wiper is superior to a felt washer, as felt tends to harden with age and shrink away from the piston rod, as well as retaining a considerable amount of dust within its fibres that is sure to wear the piston rod. A single chevron-packing wiper ring effectively prevents the entrance of foreign material, and will not retain particles of dirt and dust. The use of a wiper ring is necessary only for cylinders exposed to dust and/or moisture during operation of the airplane and can be dispensed with for cylinders inclosed within the airplane structure.

The piston rod packing is not as well lubricated as the piston packing and consequently requires more frequent adjustment. Therefore, it is necessary to provide adequate adjustment range for the packing nut and adjustment at this point should never be sacrificed for the sake of decreasing the cylinder length by a fraction of an inch.

The allowance for the piston rod and fitting is governed largely by the nature of the part to which the end fitting attaches and little variation of this dimension is possible. Sufficient allowance should be made to insure the piston rod extending at least $\frac{1}{8}$ in. beyond the

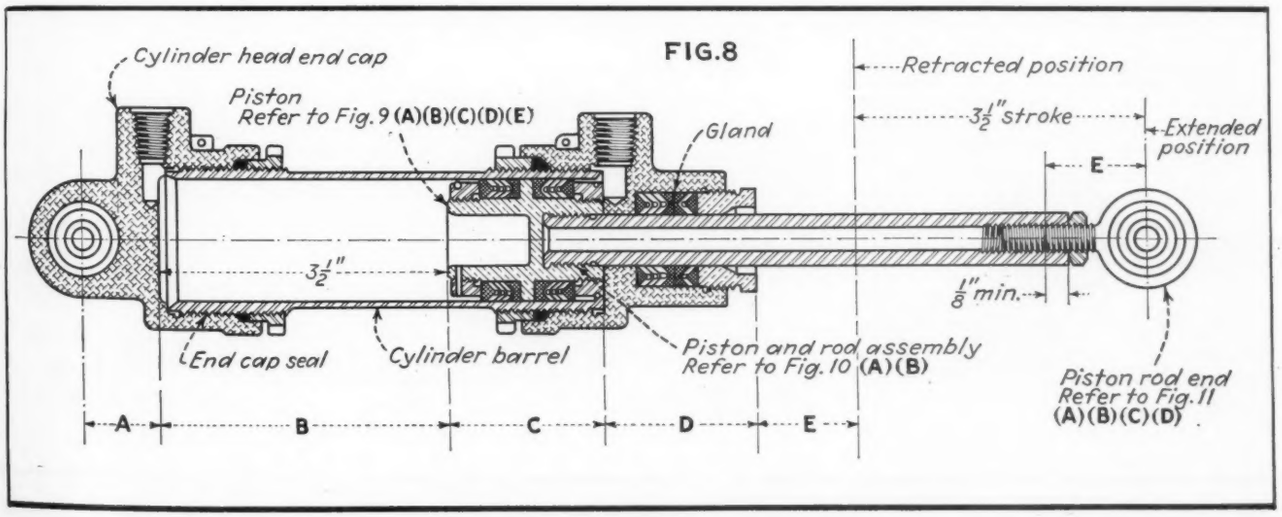


Fig. 8—Typical actuating cylinder

packing gland at fully retracted position to provide a reasonable working clearance for adjusting the end fitting lock nut when the cylinder is fully retracted.

If it is found that the minimum practical dimensions of the several factors governing the cylinder's retracted length are such that the cylinder exceeds the maximum permissible retracted length, there is no practical alternative except rearranging or redesigning the attaching structure to permit using a longer cylinder. Any attempt to surmount the difficulty by intricately tricky designs or by use of inadequate bearing areas and packings will only result in repeated difficulties during the cylinder's manufacture and subsequent service life. Whenever a design violates the established principles of machine design and hydraulics, that design is certain to cause trouble for everyone connected with it.

Piston Design

In Fig. 9 (A) is shown a detail view of the piston used in the typical cylinder shown in Fig. 8. A bronze piston body is used to provide adequate bearing material and one that will readily sweat-solder to the piston rod. The piston body is generously counterbored to reduce its weight and a pilot diameter is provided for the piston rod. Individual adjustment is provided for the packing groups and the packing is the so-called "chevron" type. Each packing group is held between an aluminum alloy packing ring and a packing gland. These packing rings and glands are separate parts, rather than being part of the piston body and packing nuts, in order to simplify their machining and reduce the total piston weight. The diametral clearance between the packing gland and piston body or cylinder wall must be considerably less than those for the packing ring, as large clearances at the gland will permit the hydraulic pressure extruding the packing between gland and piston or wall. It will be noted that the packing edges face toward the cylinder heads rather than toward the center of the piston. This arrangement has the disadvantage of the packings not being well lubricated as it is theoretically impossible for fluid to enter the space between packings. It should be used only when required by the governing specifications.

The piston design shown in Fig. 9 (B) is suitable for the large diameter cylinders and has the advantage of permitting a shorter piston length than is permitted by the design in Fig. 9 (A). The packing glands are an integral part of the piston body in order to reduce the length of the piston body without sacrificing bearing area. The packing nuts are threaded to the I.D. of the piston-body flanges, which measurably reduces the overall length but greatly increases the machining cost.

The design shown in Fig. 9 (C) is by far the most simple and practical piston design for chevron-packings, although the packing groups are not individually adjustable. It is recommended wherever it can be used without conflicting with specification requirements, and is ideal for the piston of a high-pressure hand pump. A long pilot diameter is provided for the piston-rod as it would obviously be impractical to maintain concentricity with the threads alone. Also, both piston body and nut are

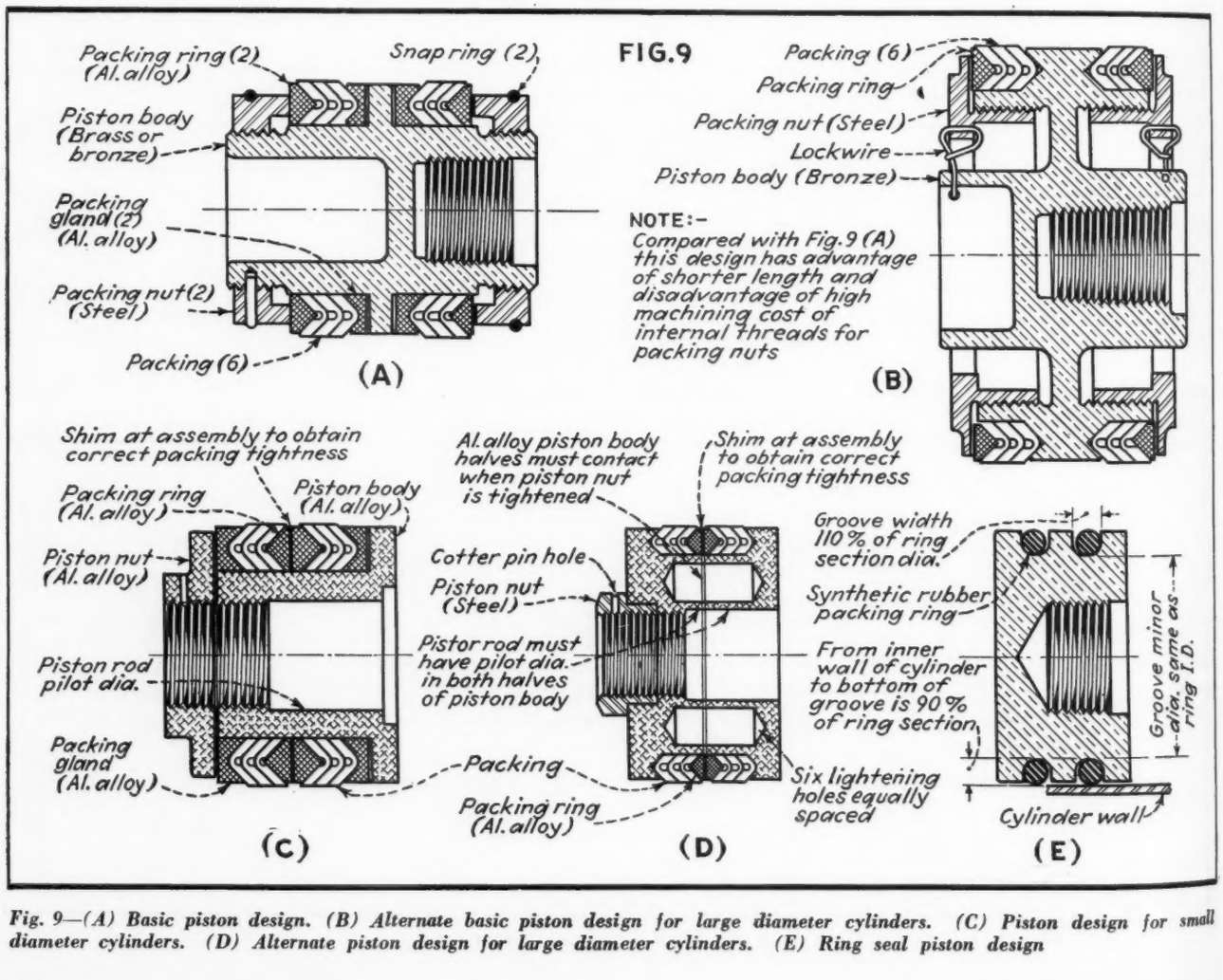


FIG.9
Packing ring (2) (Al. alloy)
Snap ring (2)
Piston body (Brass or bronze)
Packing gland (2) (Al. alloy)
Packing nut (2) (Steel)
Packing (6)
(A)
Packing (6)
Packing ring
Packing nut (Steel)
Lockwire
Piston body (Bronze)
NOTE:- Compared with Fig. 9 (A) this design has advantage of shorter length and disadvantage of high machining cost of internal threads for packing nuts
(B)
Shim at assembly to obtain correct packing tightness
Packing ring (Al. alloy)
Piston body (Al. alloy)
Piston nut (Al. alloy)
Piston rod pilot dia.
Packing gland (Al. alloy)
(C)
Al. alloy piston body halves must contact when piston nut is tightened
Shim at assembly to obtain correct packing tightness
Cotter pin hole
Piston nut (Steel)
Pistor rod must have pilot dia. in both halves of piston body
Packing
Packing ring (Al. alloy)
Six lightening holes equally spaced
(D)
Groove width 110% of ring section dia.
Synthetic rubber packing ring
From inner wall of cylinder to bottom of groove is 90% of ring section
Groove minor dia. same as ring I.D.
Cylinder wall
(E)

Fig. 9—(A) Basic piston design. (B) Alternate basic piston design for large diameter cylinders. (C) Piston design for small diameter cylinders. (D) Alternate piston design for large diameter cylinders. (E) Ring seal piston design

threaded. The seal between rod and piston is a gasket and the piston must be securely tightened against this gasket before the nut is installed. The nut is intended to bottom against the end of the piston body with thin shims being placed between the two packing rings for packing adjustment.

The packing edges in the arrangement shown in Fig. 9 (C) face toward the center of the piston body. This provides adequate lubrication of piston and packing by the hydraulic fluid, for when fluid is applied to one end of the piston it passes over the first group of packing and is sealed by the packing group at the opposite end. Thus, both packing groups are lubricated during each operating cycle.

In Fig. 9 (D) is shown another arrangement for large diameter cylinders. The basic design is similar to that shown in Fig. 9 (C), except that the piston body is divided into halves in order to permit using lightening holes to reduce the piston weight. The packing group arrangement is the same as that shown in Fig. 9 (C). A piston-rod pilot diameter is provided in both halves, as it is impracticable to maintain concentricity by means of threads.

In Fig. 9 (E) is shown a completely different piston packing design, using synthetic-rubber rings for the packing. Rubber has Shore Hardness A75-85, Shore Elasticity A70 min. For ring of 2 in. I.D. use $\frac{5}{32}$ in. to $\frac{3}{16}$ in. dia. ring section, and for other sizes in proportion. Ring section diameter should be kept to a practical minimum to minimize friction. This particular design is protected by patents and the patent situation should be investigated before planning its use. The rubber rings form an effective seal by virtue of being a comparatively loose fit in their grooves, which permits fluid pressure to act against the full width of the ring to seal by forcing the ring tightly against area represented by the small gap between piston body and cylinder wall. The effective use of this seal is dependent upon maintaining minimum clearances between piston body and cylinder wall, using rings with a small cross-section diameter in order to reduce operating friction, and providing the highest possible area differential between the pressure and static areas of the ring. One ring will seal in either direction but two are provided in order to insure an adequate margin of safety.

There are two methods in general use for attaching the piston rod to the piston, and these are illustrated in Figs. 10 (A) and 10 (B). The method shown at Fig. 10 (A) is by means of a sweat-solder joint between piston and rod, the two pieces being joined when in the rough-machine stage. All finish machining is accomplished after soldering in order to insure concentricity of piston and rod. This method is quite satisfactory when a one-piece piston body is used.

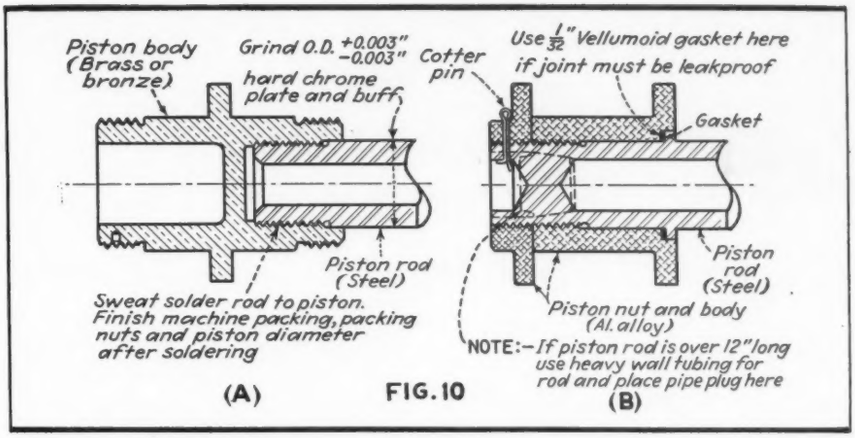

Piston body (Brass or bronze)
Grind O.D. +0.003" −0.003"
hard chrome plate and buff
Piston rod (Steel)
Sweat solder rod to piston. Finish machine packing, packing nuts and piston diameter after soldering
(A)
FIG. 10
Cotter pin
Use 1/32" Vellumoid gasket here if joint must be leakproof
Gasket
Piston rod (Steel)
Piston nut and body (Al. alloy)
NOTE:—If piston rod is over 12" long use heavy wall tubing for rod and place pipe plug here
(B)

Fig. 10—(A) Sweat-solder piston and rod assembly. (B) Gasketed assembly

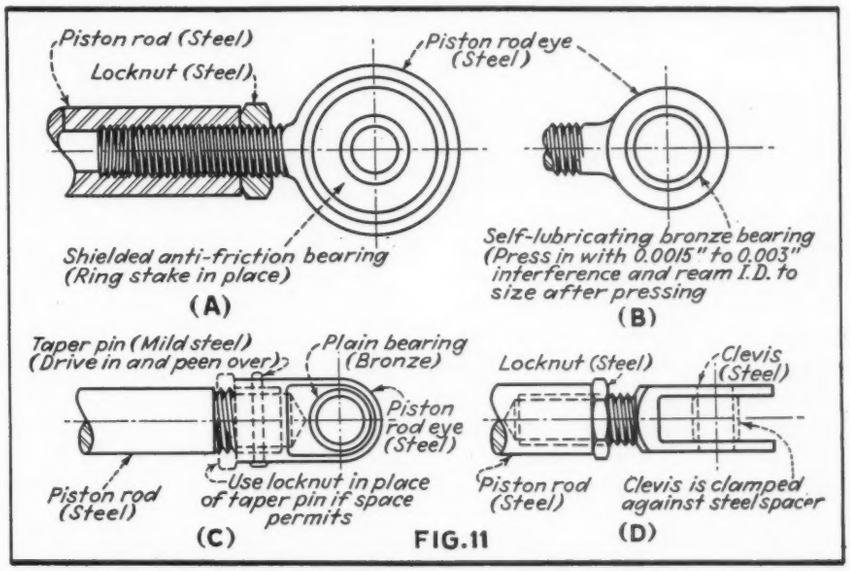

Piston rod (Steel)
Locknut (Steel)
Piston rod eye (Steel)
Shielded anti-friction bearing (Ring stake in place)
(A)
Self-lubricating bronze bearing (Press in with 0.0015" to 0.003" interference and ream I.D. to size after pressing
(B)
Taper pin (Mild steel) (Drive in and peen over)
Plain bearing (Bronze)
Piston rod eye (Steel)
Use locknut in place of taper pin if space permits
Piston rod (Steel)
(C)
FIG. 11
Locknut (Steel)
Clevis (Steel)
Piston rod (Steel)
Clevis is clamped against steel spacer
(D)

Fig. 11—(A) Lug-type rod end with anti-friction bearing. (B) Lug-type rod end with plain bearing. (C) Rod end for small diameter piston rods. (D) Clevis-type rod end

Designs employing a two-piece piston body should use a gasketed joint similar to that shown in Fig. 10 (B). When this arrangement is used it is necessary to provide a generous pilot diameter for piston body and thread the piston body to the rod. This insures concentricity of the parts and prevents "working" of the gasket under pressure. The shoulder on the piston rod for the gasket is recessed within the piston body to minimize the piston's overall length.

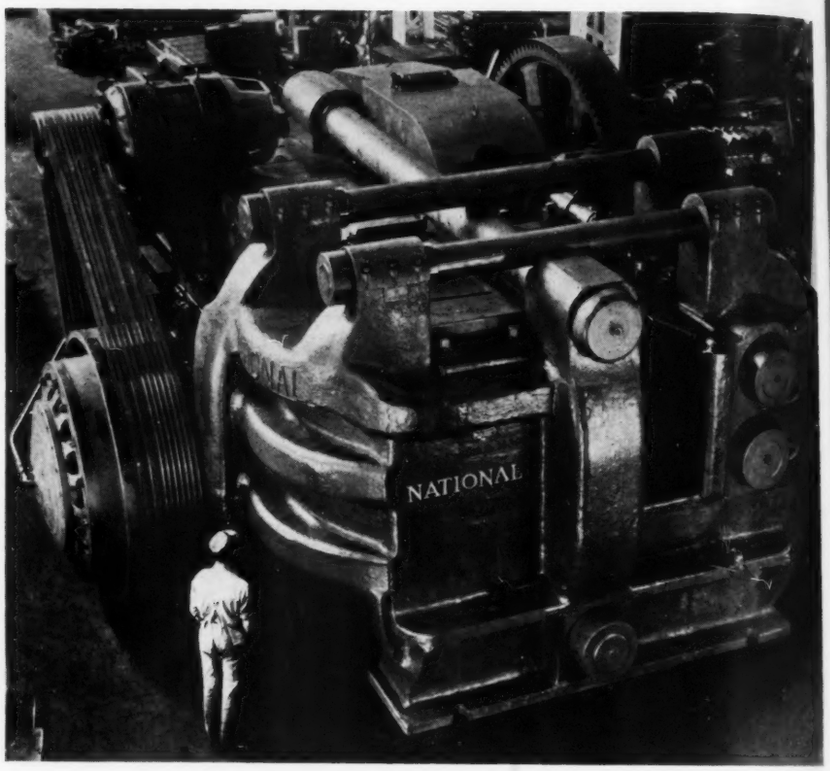
The piston rod for the design shown in Fig. 10 (B) can be machined from bar stock for short piston rods. Long piston rods should be machined from heavy-wall tubing swaged down at one end for the piston bearing-diameter. The open end of piston rods formed from tubing can be closed with a pipe-plug sweat-soldered in place. All piston rods should be ground to a nominal diameter two-thousandths of an inch smaller than the design nominal diameter, and then hard-chrome plated with a plating 0.001 in. thick. After the plating operation the rod should be buffed to a high polish.

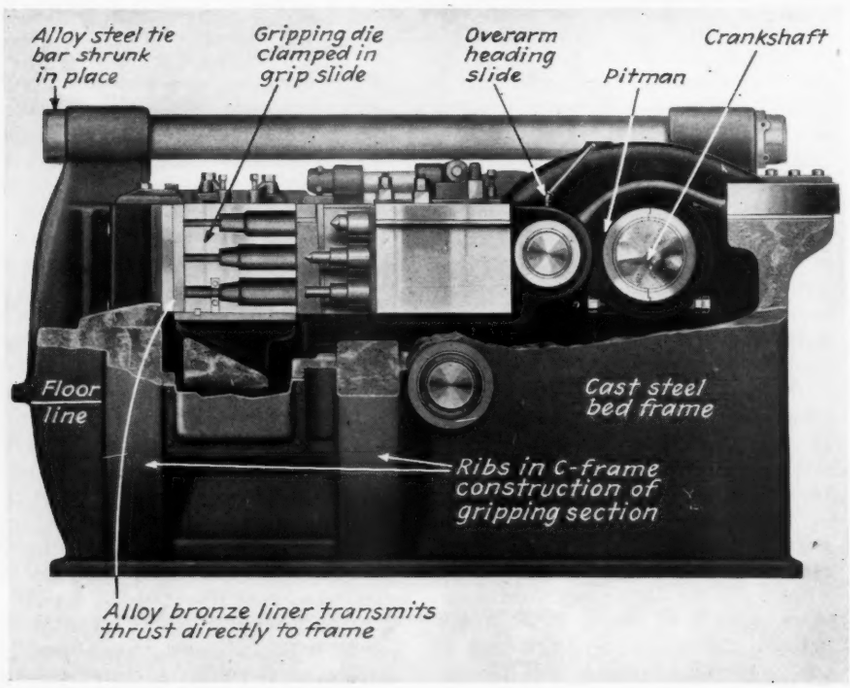
Several conventional forms of piston-rod end-fittings are shown in Figs. 11 (A) to 11 (D). All but one of these are threaded to the piston rod and are provided with a lock nut for adjustment purposes. The design shown in Fig. 11 (C) is suitable for small-diameter piston rods in cylinders wherein stroke adjustment is unimportant, but should never be used for important cylinders. Use anti-friction bearings for the rod ends of frequently used and/or heavily loaded cylinders. Use plain bearings for infrequently used and/or lightly loaded cylinders.

Modern Designs

Giant Cast Steel Frame Designed for Rigidity

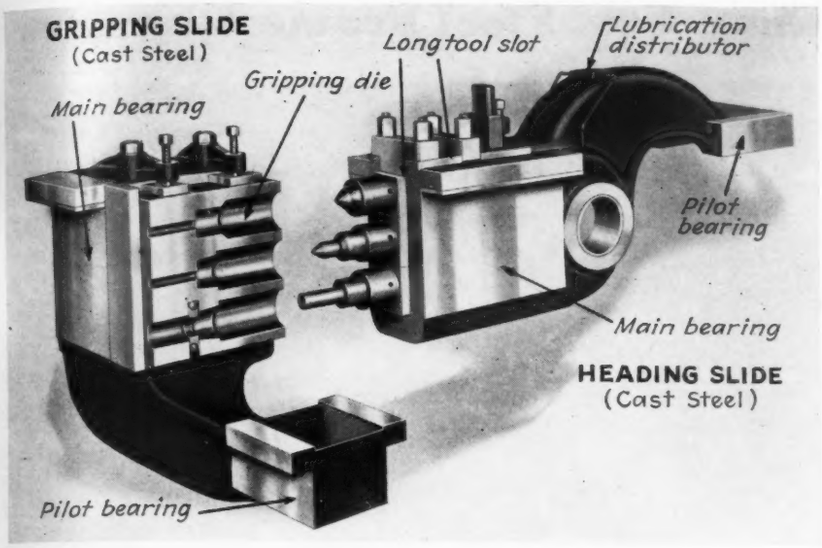
Rigidity and accuracy are achieved in this large forging machine by compact design which reduces bending moments and "spring" of the frame to a minimum, resulting in greater accuracy. Flywheel shaft is mounted in the neutral axis of the bed frame and the overarm heading slide permits locating the main shaft farther forward without sacrificing tool alignment. The forging machine, built by National Machinery Company, is rated at 9 in. capacity and weighs more than 500,000 lb. — greater than the combined weight of 140 automobiles. It is producing airplane engine cylinder forgings.



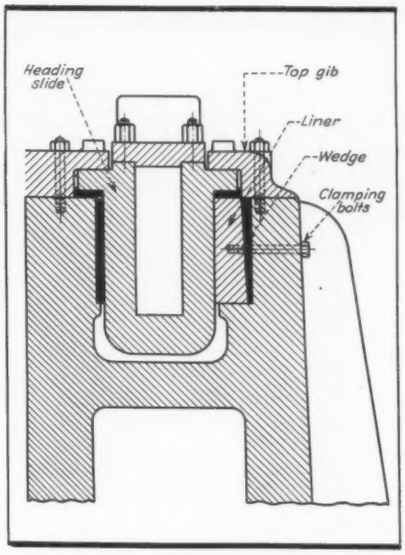

Alloy steel tie bar shrunk in place
Gripping die clamped in grip slide
Overarm heading slide
Pitman
Crankshaft
Floor line
Cast steel bed frame
Ribs in C-frame construction of gripping section
Alloy bronze liner transmits thrust directly to frame

Short and deep bed frame, of heat-treated cast steel, extends below floor line and has heavy sections for greater rigidity. For shipping reasons, it is cast in two pieces securely clamped by four large forged steel tie bars shrunk into position. Hardened and ground steel liner is loosely tongued to gripping slide. This liner bears against hardened and ground tool steel liner secured to bed frame with bronze wearing plate between. Heading or upsetting thrust is thus transferred directly to bed frame.

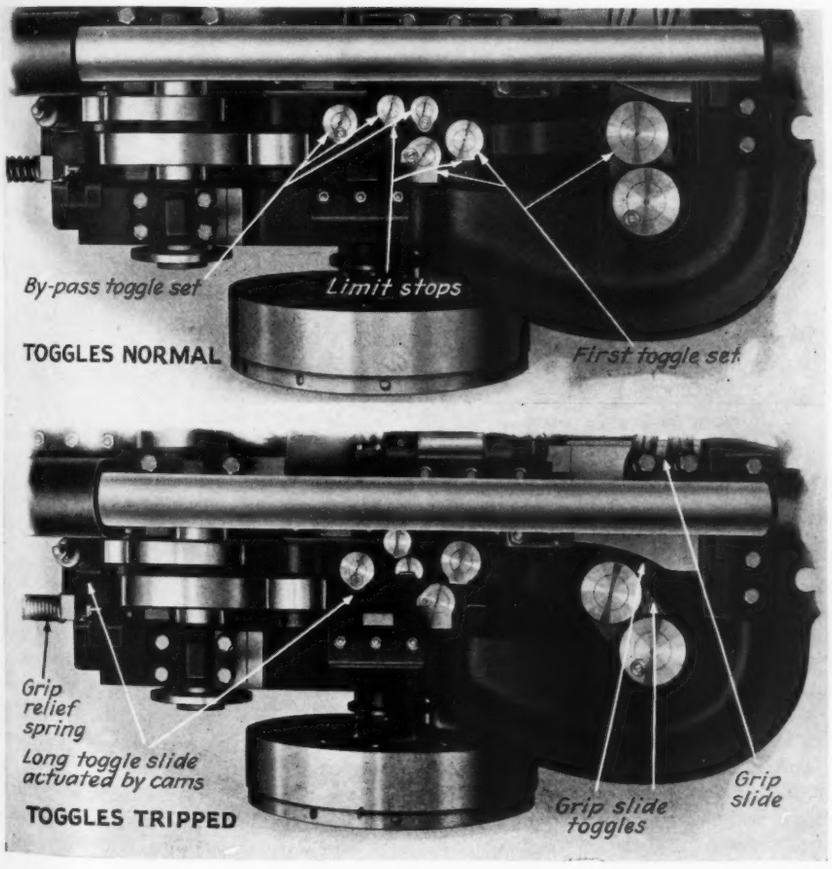
Main shaft is turned from double heat-treated steel forging, forged with 4 to 1 reduction. Pinion shaft also is hardened and ground steel forging. Bearings of main shaft are special analysis bronze. Pinion shaft is mounted in roller bearings. Pins in toggles and pitman are ground, and operate in nickel bronze bushings. Motor is mounted on tilting platform adjustable for correct V-belt tension.



Pilot bearings on underarm gripping slide and overarm heading slide lengthen the effective bearing and give bearing support far from the center of rotation so that the slides can neither sag nor tilt in their ways. Outboard bearing of gripping slide is elevated above the arm to prevent entrance of scale and water. The arm of the heading slide extends over the main shaft to a pilot bearing behind the shaft, permitting a long slide without sacrificing compactness of the frame. Heading slide also has a long tool slot, and heading tools have long shanks so that tools cannot be forced out of alignment by heavy forging pressures. This construction of slides and tool holders makes possible better accuracy, less flash, more effective gripping action, and less uneven wear on the ends of the bearings. Both gripping and heading slides are of heavy cast steel construction designed for maximum strength and rigidity.



Design of slide bearings provides take-up for wear by a simple wedge adjustment. To remove side play from slides, top gib is removed, clamping bolts are loosened, and adjusting wedge is raised from position. Required thickness of sheet metal packing is then slid into place between wedge and liner, and the wedge is adjusted and clamped. This design eliminates necessity for removing slides and liners, replaning and refitting.



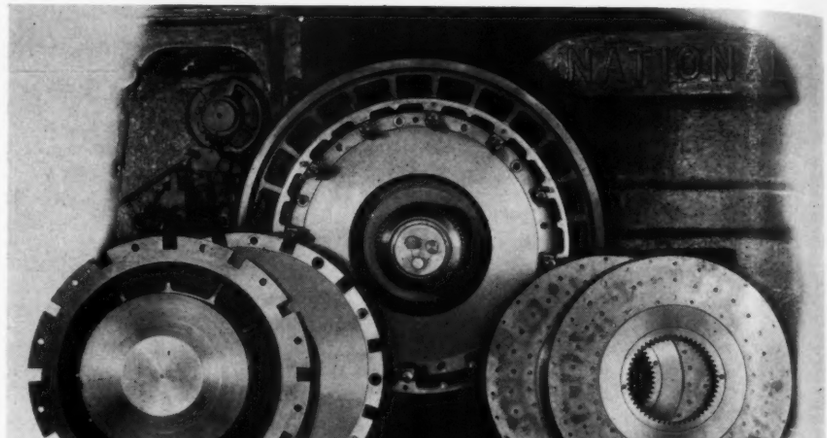
Double sets of toggles, held in position by heavy spring pressure, serve as an automatic grip relief to prevent damage caused by improper positioning of stock or improper die set-up. When closing pressure on gripping slide becomes excessive, relief toggles trip and gripping dies are immediately thrown open, permitting the heading tool to push the stock out of the die with no damage to die or toggle bearings. As main shaft continues to rotate, a cam on the main shaft returns the toggle slide, resetting relief toggles automatically to operating position.

Illustration of toggles in normal position shows that small angularity of the first toggle set throws only a small portion of the pressure against the by-pass toggles. Result: only relatively small pressure is required from grip relief spring which tends to keep by-pass toggles closed. If a single set of toggles had been used, the toggle angle would be too small, spring pressure too heavy, and the mechanism would not be sensitive enough to overloads caused by thin fins or slight misalignment.

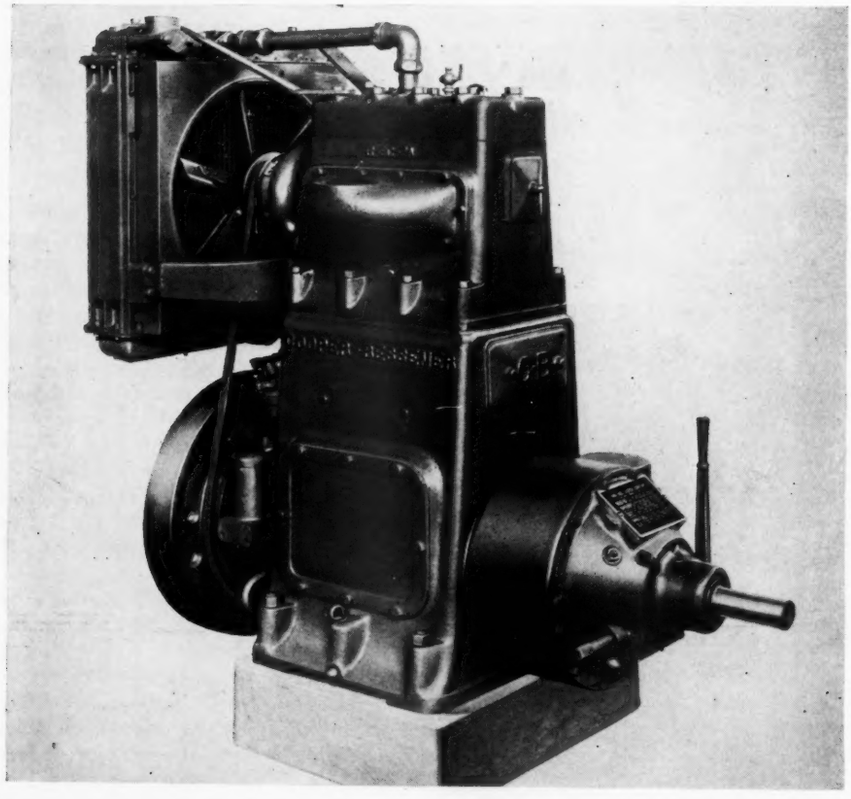
Toggles are interlaced, both in the grip slide and bed frame, and bearings are full die height. This construction of joints insures uniform bearing pressure. *(Continued on next page)*

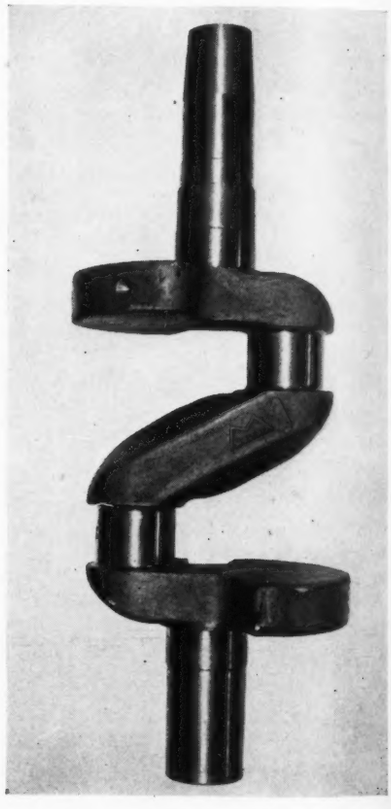
MODERN DESIGNS – Giant Cast Steel Frame (*Continued*)

Air-cooled friction clutch eases tremendous starting torque. The clutch is actuated instantly by a pedal valve, and starts the heading ram rapidly and smoothly. Two friction plates rotate with the flywheel shaft and are sandwiched between three floating plates which are keyed to flywheel by lugs in peripheral slots. Clutching pressure is applied by air pressure in large-diameter, short-travel cylinder at center of flywheel, assuring even pressure on friction surfaces. Clutch plates are surrounded by many air vents and vanes which cause a powerful blast of air to circulate around the plates when clutch is rotating. Design is such that no dirt can get between the clutch plates, and the assembly can be taken apart without disturbing the bearings of the flywheel or the machine proper.



Gas Engine Has Cast Meehanite Crankshaft



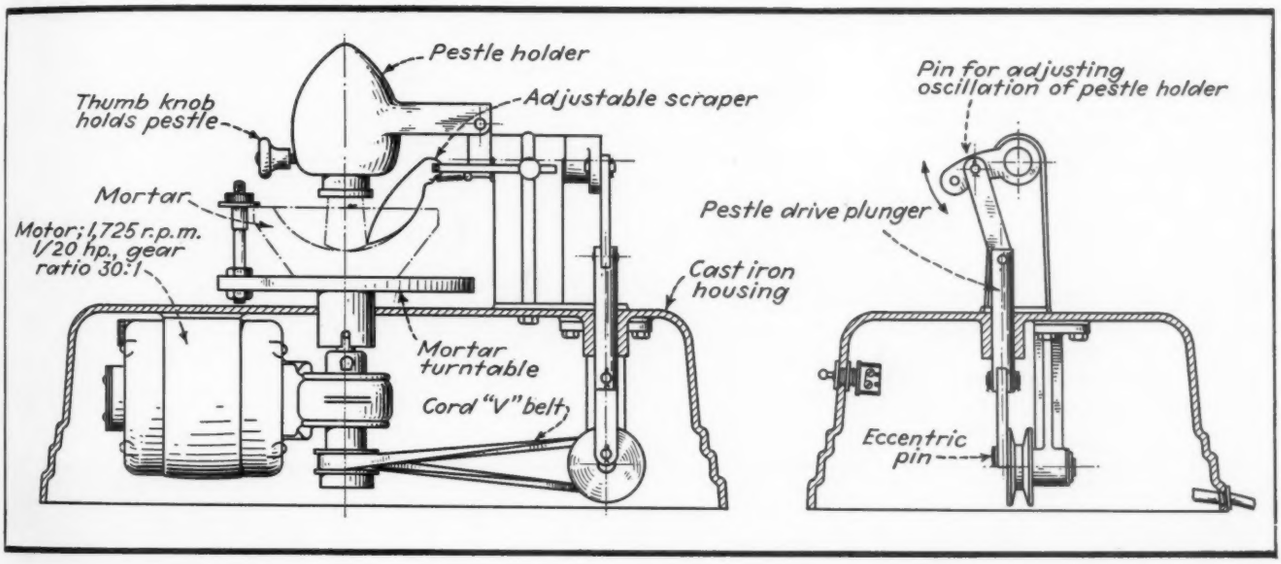


Eliminating high cost of forging dies, and providing better damping qualities, crankshaft of this 25-hp., 600 r.p.m., 2-cycle gas engine is cast of Meehanite iron. Before cast crankshaft was adopted, it was thoroughly tested in lathe which produced rotational off-center deflection. Cast crankshaft withstood 10,000,000 reversals at 23,700 lb. per sq. in. stress, then withstood 10,000,000 reversals at stress loading of 26,100 lb. per sq. in. Off-center deflection was again increased to equivalent of 29,150 lb. per sq. in. stress, and failure developed at 15,000 reversals. Forged shaft outlasted cast shaft in test, but cast shaft had entirely satisfactory life, plus better damping qualities. Cost comparisons show $1,700 die cost for forged crankshafts. This cost is to be spread over ultimate sales of approximately 1,000 engines with average shop order size of 10 to 100 units. Machining costs compare closely except where there are crank-weights which must be assembled on forging, but which can be cast integrally on cast shaft.

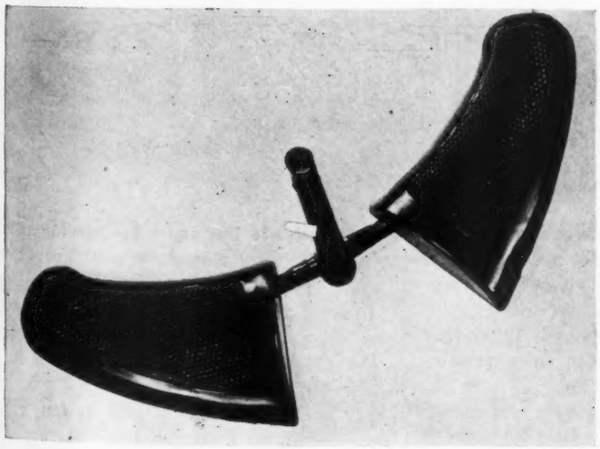
Standard Gear Motor Drives Mortar Grinder

Relatively small market for scientific apparatus limited the redesign of Fisher Scientific Company's mortar grinder to simple castings and standard drive units. The only high-speed shafts in the grinder are in the standard motor and worm-gear unit. These are permanently lubricated. Pestle and turntable drives are slow speed and require no bushings. V-belt drive to pestle rotates a pulley mounted on cast iron column. Crank mechanism is an off-center pin in pulley and operates pestle drive plunger through a connecting rod. Motion from plunger is transmitted to pestle holder mechanism, causing pestle to rock back and forth in the revolving mortar. Grinding pressure is from weight of pestle and pestle holder, which can be swung up out of the way. All driving parts are protected and are below the mortar so that no oil or grease can fall into the sample.

Principal research jobs were determination of best pestle pressure (hence weight of pestle holder) for all samples, and determination of proper relationship between speed of mortar table and oscillation of pestle so that pestle does not retrace its path within many cycles.



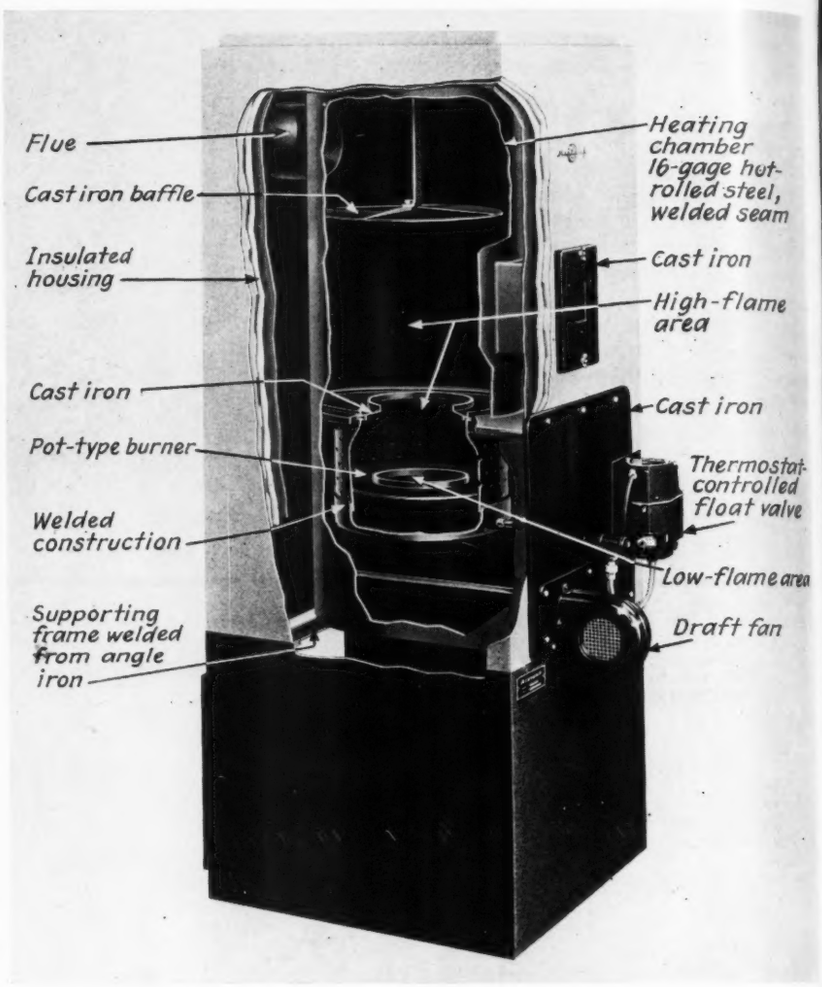
Plastics for Gun Grips, Bayonet Handles



Pistol grips molded of cellulose acetate will relieve other materials in police and air-raid warden pistols, although this thermoplastic does not meet new rigid Army specifications. Phenolic molded plastics with cotton flock filler has recently been standardized by Ordnance for Army pistol grips, machine gun slides and bayonet handles. Still in early development stage, some plastic pistol grips have been deilvered to troops and the material is being promoted as an alternate for walnut grips and for benefits of mass production. Army specifications are stringent. Color: dull walnut, greyish, dark or imitation walnut; must not be bright or transparent; finish is dulled by sandblasting. Strength: must be tough, able to take all knocks and hard usage of standard phenolics. Must not crack or break at temperatures as high as 170 deg. F. Must pass boiling oil test and have low water absorption. Material: contractors must supply their own. Government does not care who does the job.

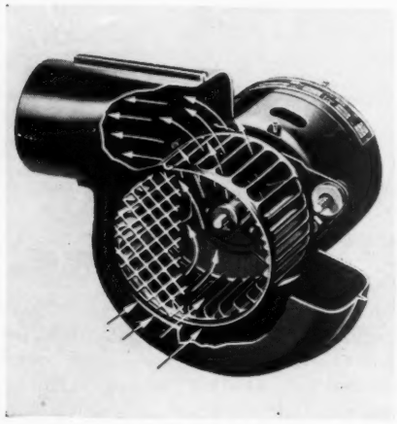
MODERN DESIGNS – Oil Furnace Has Triple Insulation

By keeping the design simple, by insulating well, and by careful design of the vaporizing pot-type burner, Airtemp Division, Chrysler Corporation produces this small-home oil furnace claimed to cost no more than a hand-fired furnace. Except for a few simple iron castings, entire unit is of sheet steel construction with welded frame.

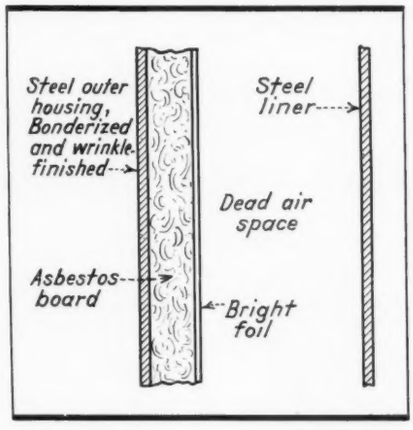


Supporting frame is welded from angle iron, and housing is mounted with interlocked seams to prevent air leakage. Heating chamber is 16-gage hot-rolled steel with welded seams. Sheet at lower end of chamber is cut and opened out to form access area which is covered at front of cabinet by cast iron plate. Top, bottom, and air inlet baffle of heating chamber are welded in place.

Pot-type burner has no moving parts, is designed so that flame is clean no matter whether it is low or high. Bottom of pot is heated just enough to vaporize the oil flowing into it from the thermostat-controlled metering unit. When oil flow is small, flame burns from the lower opening. This is a pilot flame and never goes out. When oil flow is large, vapor mixes with air entering holes in upper chamber, and flame burns from upper hole in the pot.



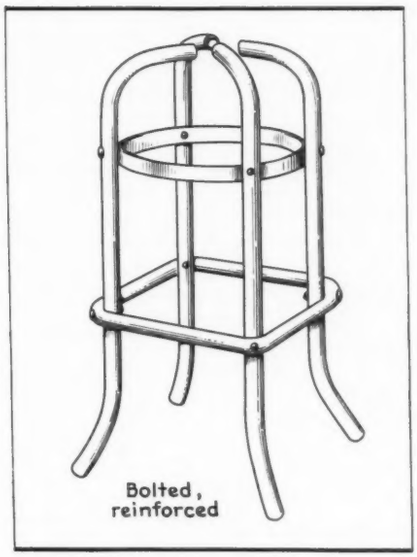
Draft fan is small centrifugal blower (20 watts, 1,500 r.p.m.) bolted to front of cabinet by simple angle brackets. By providing constant air supply, the flame can be held uniform in all weather. Fan motor is automatically controlled and turns on when high flame is desired. Enough air to feed the low flame can pass through blower when stopped.

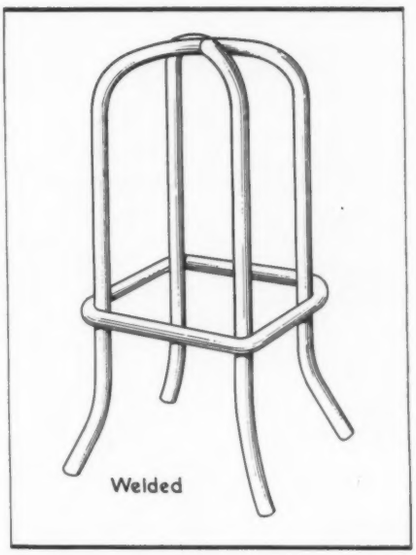


Undesirable heat loss is prevented by triple-insulated cabinet. Insulation zones are (1) dead air space, (2) radiant-heat-reflecting polished metal foil, and (3) asbestos mill board. Insulation extends down to bottom of pot only. Heavy-gage sheet steel cabinet is Bonderized to prevent rust and corrosion. Finish is two-tone wrinkle finish.

Forced-air furnace has fan mounted in base. Fan may be either propellor type or centrifugal type with air filter (shown above). Fans increase heating as shown by comparison of free air delivery: No fan—50,400 b.t.u. per hr., 470 cfm.; propeller fan—50,500 b.t.u. per hr., 825 cfm.; centrifugal fan with filter—56,000 b.t.u. per hr., 710 cfm.

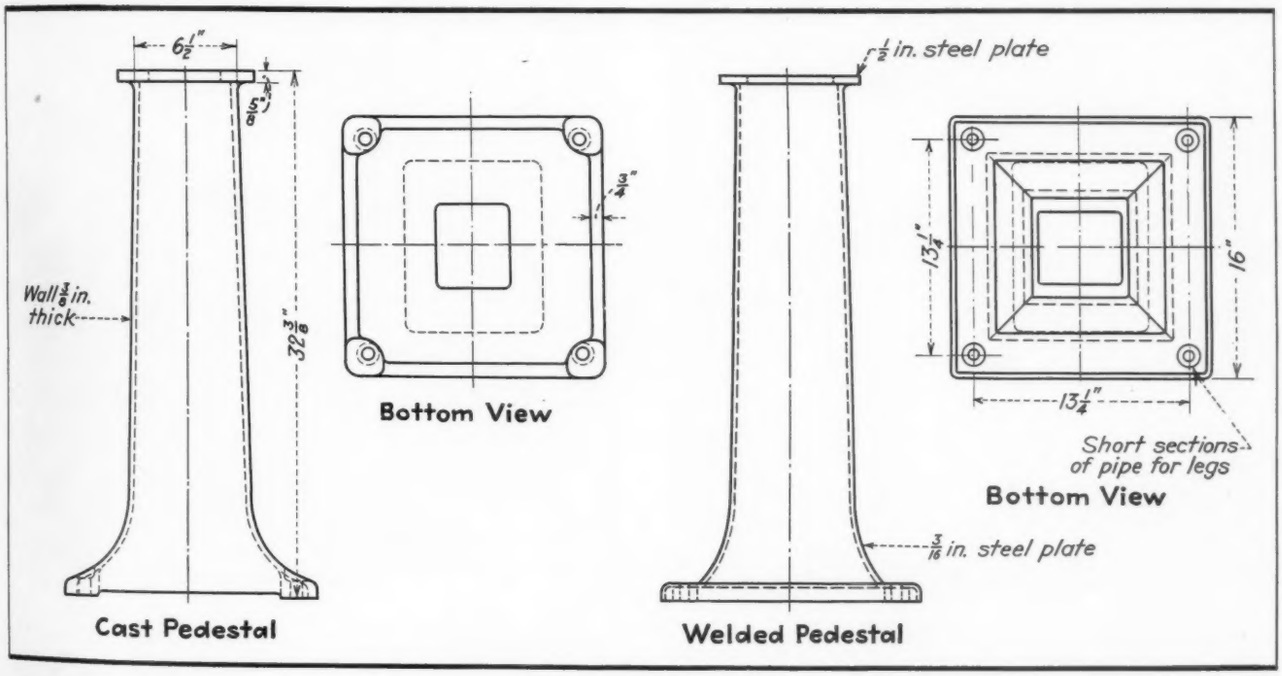
Bar Stool Strengthened By Welding





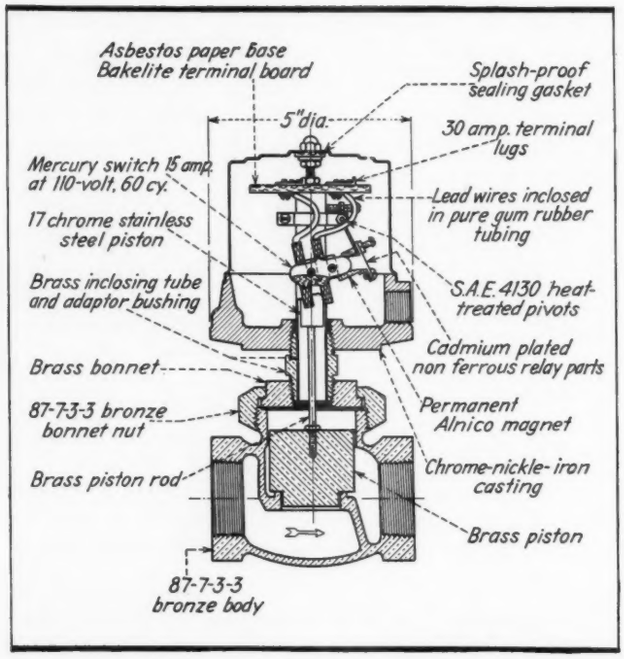
Steps in design of Art Chrome bar stool, beginning with original stool which had four pieces of 1-in., chromium-plated tubing as legs. Footrest was tubing bent into square with ends joined by gas welding. Pieces were assembled by ¼-in. bolts and lock washers. The design was later strengthened by bolting a round steel hoop to the legs near the top. Final step was design for welding. Two of the legs are now formed from continuous tube and reinforcing ring is eliminated. Welds are made on underside of footrest tube. Chromium plating is burned for 1 in. during welding operation but when cleaned with steel wool and aluminum painted, the weld is hardly visible.

Buffer Pedestal Now Welded To Save Weight

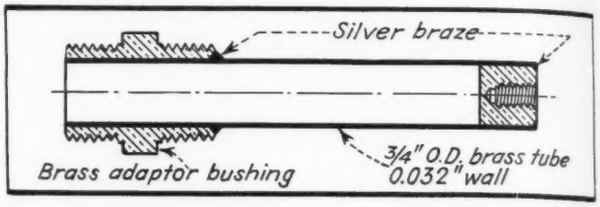


Weight of pedestal for U. S. Electrical Tool Company buffer has been reduced from approximately 250 lb. to 72 lb. by switching from iron casting to welded construction. Walls of new pedestal are four flame-cut pieces of $\frac{3}{16}$ in. steel plate. Base also is $\frac{3}{16}$ in. plate, notched at corners, flanged and welded. Four short pieces of steel pipe, welded just inside corners, form strong supporting legs through which floor bolts pass. Top plate is ½ in. thick. After welding, joints are ground smooth. Exception is welded joint between walls and base plate; this is smoothed by using ordinary surface filler. When painted, welded pedestal is hardly distinguishable from cast pedestal.

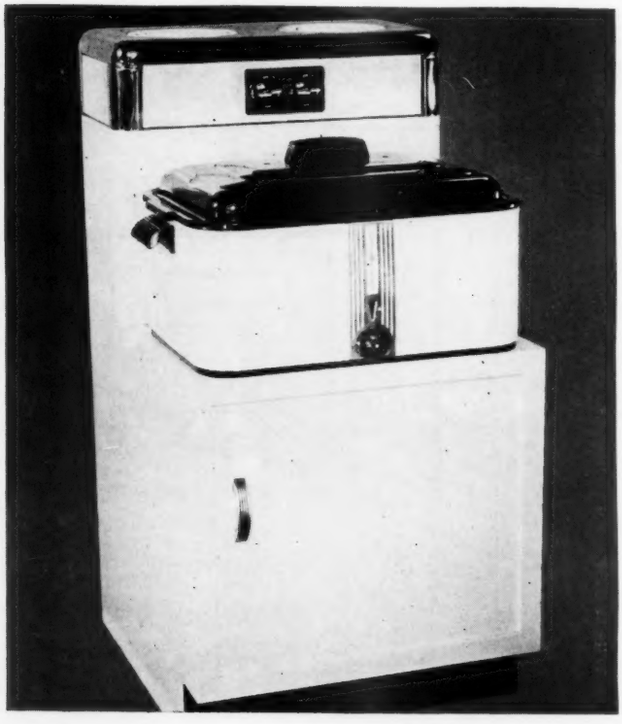
MODERN DESIGNS – Flow Alarm Magnetically Operated


Asbestos paper base Bakelite terminal board
Splash-proof sealing gasket
5" dia.
30 amp. terminal lugs
Mercury switch 15 amp. at 110-volt, 60 cy.
Lead wires inclosed in pure gum rubber tubing
17 chrome stainless steel piston
Brass inclosing tube and adaptor bushing
S.A.E. 4130 heat-treated pivots
Cadmium plated non ferrous relay parts
Brass bonnet
87-7-3-3 bronze bonnet nut
Permanent Alnico magnet
Chrome-nickle-iron casting
Brass piston rod
Brass piston
87-7-3-3 bronze body

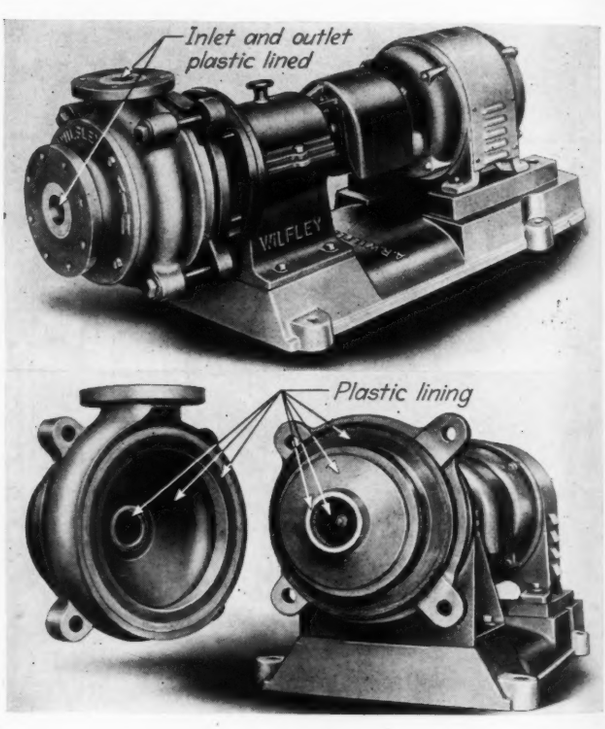
Flow alarm, which tells when sufficient flow of water, oil, gas, or air is passing through pipe, is actuated by a unique magnetic device which eliminates stuffing boxes or bellows. It consists of full ported globe valve body to which is attached a Schaub Magnetrol switch. Permanent magnet and mercury switch are mounted on a pivoted armature. When flow starts, brass piston in the valve rises, lifting stainless steel piston in the inclosing tube. This piston attracts the magnet, tilting the mercury switch. When flow stops or reduces to a predetermined minimum, the stainless steel piston drops down out of the magnetic field and the armature swings outward.



Inclosing tube is silver-brazed for permanent fluid-tight seal. Air trapped in this tube prevents entrance of liquids; thus the stainless steel piston cannot be clogged by solids carried in the fluids. Unit can easily be removed.



War necessitates a new type of design, typical of which is this General Electric kitchen package for housing projects where low cost, production speed, limited space and portability are main considerations. Unit is standard roaster and hotplate mounted on specially designed cabinet. Roaster is thermostat-controlled, has porcelain enameled lid. Accessory dishes are glass. Hotplate has two open-coil units, one of 1,000 watts, the other of 650 watts. Cabinet is welded sheet steel with baked enamel finish.



Corrosive solutions do not come in contact with metals in this Wilfley centrifugal pump. Pump case, impeller, and case plate are lined with phenolic resin (Haveg 41). Design of impeller is such that no stuffing box or packing is necessary around shaft. When pump is stopped, a conical seal on the shaft is seated by spring pressure. When pump is running, a governor moves the shaft $\frac{1}{16}$ in., opening the conical seal and eliminating rubbing contact; centrifugal action prevents leakage. Motor speeds are usually 1,800 r.p.m.

SELENIUM RECTIFIERS – I

Characteristics, Applications and Design Factors

CAROLE A. CLARKE
International Telephone & Radio Development Corporation

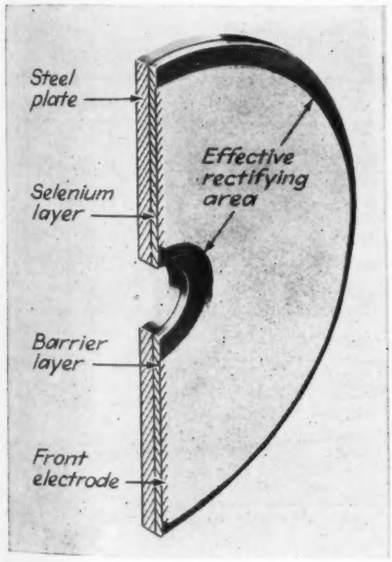
BECAUSE of their long life, reliability, flexibility and economic advantages, selenium rectifiers of all sizes are finding diversified application in every branch of defense work. They are used by military and naval forces and by the industries which supply them, both as part of the products themselves and in manufacturing equipment.

A rectifier is defined as a device possessing the ability to pass electric current freely in one direction while offering much greater or almost total resistance to the passage of electric current in the reverse direction. Thus, crystal detectors may be classified as rectifiers, though their power capacity must be measured in microwatts as compared with kilowatts handled by metallic-junction rectifiers of much greater effective rectifying surface. The ideal rectifier, if such exists, would offer zero resistance to the flow of current in the forward direction and infinite resistance to the flow of current in the reverse of blocking direction. Lacking ideal rectifiers, selection must necessarily be made from available types with proper consideration of important factors such as first cost, useful life, annual charges, size, weight and efficiency.

Selenium rectifiers differ in their construction from other rectifiers of the metallic-junction type, principally in the electrodes themselves and in their semi-conducting layers. In these rectifiers the semi-conducting layer is derived from the metallic element selenium which is found in practically unlimited quantities in North America. This layer consists of the thinnest practical coating (approximately 0.05 mm.) of high purity selenium applied to one side of a processed steel plate which serves as the back electrode. The selenium coating is itself covered with an alloy serving as a low resistance front electrode and providing uniform distribution of current throughout the active material. Heat-treatments create a barrier between the front electrode alloy and the selenium, resulting in increased difference in resistance for currents flowing in the forward and reverse directions. Current flows readily from the back electrode to the front electrode, that is, in the steel to selenium direction, but practically not at all from selenium to steel. Each plate thus constitutes a valve or half wave rectifier. Full wave rectification is obtained with two or more half wave elements in one of the conventional single or three-phase circuits.

Fig. 1 illustrates the construction of a selenium rectifier plate in cross section but does not represent the relative thicknesses of the various layers. Besides serving as a back electrode the sturdy steel plate provides rigid support, giving the strength necessary to withstand physical shocks, vibration and stresses. The steel also provides the necessary surface for convection cooling under all normal operations. Rectification takes place entirely within this one-piece sturdy plate.

The plates range from ¾ in. to 4⅜ in. in diameter, seven sizes in all; they may be assembled in compact stacks consisting of the plates, contact discs, spacers, insulators, terminals and a center stud with or without mounting brackets. Parts of a rectifier stack are shown in Fig. 2. The flexible, petal-shaped contact discs are of brass and make contact with a considerable area of the rectifier plate. Contact terminals are brought out from the plates in various arrangements for series or parallel con-



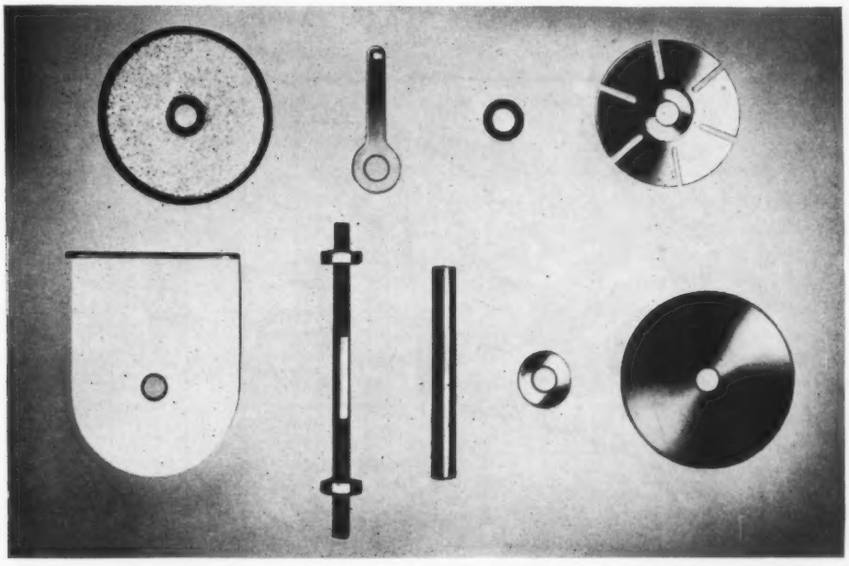


Fig. 1—(Left) Cross-section of a selenium rectifier plate. Fig. 2—(Right) Components of a selenium rectifier stack. The top row, in the usual order, shows a rectifier plate, terminal lug, pressure limiting washer, and petal-shaped contact disk. The lower row shows a mounting bracket, center stud, insulating sleeve, spacing washer and end insulator

nection of the plates, as required. Since each plate is a complete rectifying element, pressure is not required beyond that necessary to establish electrical contact and the rectifier therefore is not critical to pressure changes. The electrical parts of the stack assemblies are completely insulated from the stud and mounting brackets. If necessary, high potential tests of individual stacks may be applied up to 3,000 volts a.c., thus exceeding A.I.E.E. requirements.

Unlike thermionic rectifiers which depend upon heat to produce electron emission, the d.c. output from a selenium rectifier is available immediately upon application of the alternating voltage, avoiding the delay of a heating-up period. The materials of selenium rectifiers do not deteriorate during normal operation. There are no moving parts or materials requiring maintenance or renewal.

The rectifier stack is essentially an assembly of compact, light metal parts ruggedly built to outlast associated equipment. An assembled selenium rectifier stack is shown in Fig. 3. It will be noted that the rectifiers are designed for mounting with the assembly stud in a horizontal position so that normal air convection provides for all but unusual cooling requirements.

With proper protection of metal parts by means of suitable coating or oil immersion, selenium rectifiers can be used under unfavorable atmospheric conditions. The normal separation of electrical parts permits their use at high altitudes.

High permissible reverse voltages and working temperatures make it possible to obtain high power output with a small quantity of plates. These

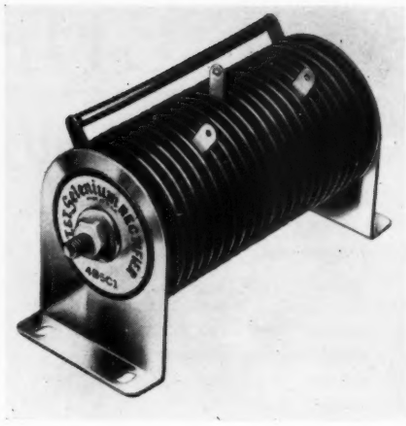


Fig. 3—A standard type of rectifier stack

factors permit light, small rectifier stacks. Relatively large unobstructed cooling surfaces permit the use of small diameter plates. Rectification occurs over a wide range of applied frequencies.

Static forward and reverse characteristics of a selenium rectifier are shown in Fig. 4. Attention is directed to the fact that the reverse current is plotted to two scales because of its low values. The ordinate for the dotted reverse current curve is only 1/100th of that used for the solid line. The curves represent the static characteristics of a selenium rectifier plate of one square centimeter effective area. The characteristic always passes through the origin with the current increasing rapidly for low values of forward voltage and finally becoming almost linear. Because of its low resistance in the forward direction and high resistance in the reverse direction, a high rectification ratio with good regulation is attained.

The negligible reverse current or "back leak" shown as a solid line in Fig. 4 finds a valuable practical application in battery charging rectifiers through the elimination of equipment for disconnecting the battery from the rectifier when the rectifier is turned off or the a.c. supply is interrupted. This characteristic also makes possible the use of one or more plates connected as a valve between an automobile or airplane generator and its associated battery in place of the usual cutout relay. When the generator voltage exceeds that of the battery, current flows through the valve to charge the battery, but when the engine driving the generator slows or stops, the high back resistance of the valve prevents battery discharge through the generator.

A further example of valve action is presented by the connection of a rectifier plate of appropriate size across an inductance in a d.c. circuit for quenching the arc across a disconnect switch or contactor. The valve is so connected that it does not pass the d.c. impressed on the inductance, but when the d.c. circuit is broken, the inductance discharges through the low resistance path of the valve with practically no increase in the voltage across the inductance. Resistance may be inserted in the valve circuit to adjust the rate of current decay.

Unlike most electrical apparatus, the forward resistance characteristic of the selenium rectifier as a function of plate temperature has a negative slope. The resistance decreases rapidly as the temperature increases from low values, but only slightly in the usual range of working temperatures. The upper curve of Fig. 5 shows the relative drop in voltage across a plate, or its decrease in resistance, with temperature rise, for

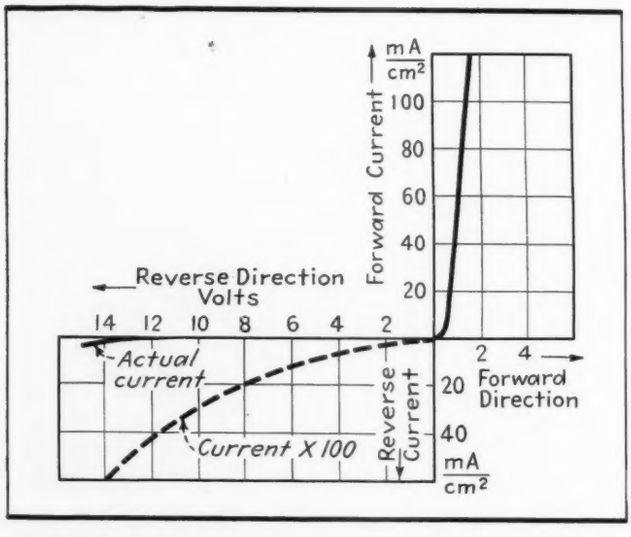


Fig. 4—Typical forward and reverse current characteristics. Reverse characteristic shown to 2 scales

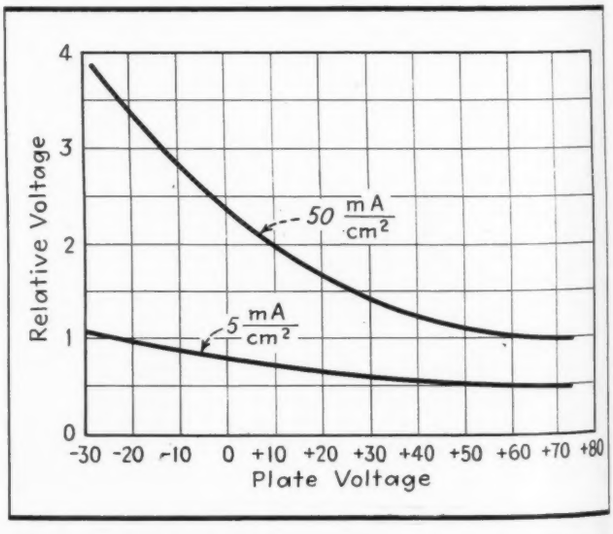


Fig. 5—Forward voltage change with temperature for full load and one-tenth full load

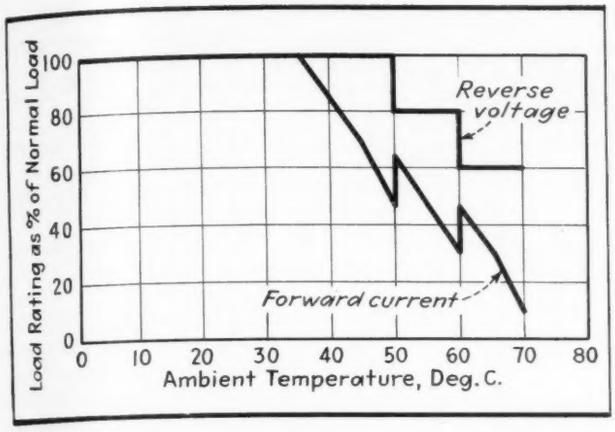


Fig. 6—Load rating versus ambient temperature. Load rating decreases as ambient temperature rises

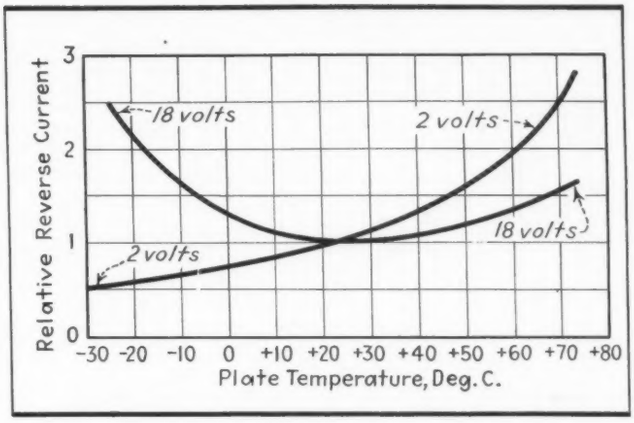


Fig. 7—Reverse current variations with plate temperature for normal voltage and a fraction of normal voltage

a constant full load current density. It should be noted that the total recifier forward resistance is only about 10 percent of the total load circuit resistance; hence, the change in the rectifier voltage drop is a quite negligible percentage of the value of the output voltage.

Variation in reverse resistance at 2 and 18 volts, respectively, is indicated in Fig. 7 for the same range of plate temperatures. Actual resistance values are different but, in order to show the form of the two graphs on one illustration, both the 2 volt and 18 volt reverse currents are assumed as unity for a rectifier temperature of 25 deg. C. It is obviously of fundamental importance that the reverse resistance be and remain high even under extreme temperature conditions.

The relatively small change in reverse current with temperature contributes to the high efficiency of the rectifier and extends its usefulness over a wide range of temperatures.

From a dynamic standpoint, the negative resistance characteristic of the selenium rectifier tends to produce a forward current wave shape in which the successive half wave pulses deviate slightly from true sine wave form because of the minute changes in forward resistance which follow the cyclic change in input voltage. Although current and voltage pulses are in phase in the rectified output, the measured wattage does not exactly equal the product of the measured effective current and voltage because of the harmonic content of the output. Thus the measured rectifier power factor differs slightly from unity and is found to be of the order of 97 percent to 99 percent in single-phase rectifiers, depending on conditions of use.

Both the forward and reverse resistances of the selenium rectifier increase with age, causing a higher internal drop and consequent decrease in output voltage, which is offset to some extent by the smaller loss in the reverse direction. Aging usually takes place within the first 10,000 hr. of full rate continuous operation. In intermittent or light load operation this period is longer; in extreme cases, 40,000 to 50,000 hr. A new rectifier will show no change in output for a considerable length of time and, once it has fully aged, no additional changes in output occur. The shape of the aging curve and the time required are functions of the specific conditions of use and cannot readily be predicted. If full compensation is required, the a.c. input voltage may be raised after aging to restore the d.c. output to its original value. Experience shows that in the majority of cases aging can be entirely neglected.

Selenium rectifiers are designed with adequate self-cooling facilities utilizing normal air convection. Forced draft cooling may be employed and operation under oil is practicable for both protection of metal parts and cooling.

Since the forward resistance of a selenium rectifier is not zero, as shown in Fig. 4, the forward flow of current generates heat. The small flow of current in the reverse direction also adds to the heat generated within the plate. The alloy employed as the front electrode has a lower melting temperature than the selenium; the melting temperature of the alloy, therefore, sets the absolute maximum temperatures at which the rectifier plates can be operated. Considerations of safety require that the temperature rating of selenium plates be established with an ample margin of safety below this limiting maximum temperature.

Like most electrical power equipment, selenium rectifiers are designed for a temperature rise of 40 deg. C. above an ambient temperature of 35 deg. C. (95 deg. F.) for continuous operation. Their maximum safe plate temperature of 75 deg. C. (167 deg. F.), for aged plates, affords an ample safety factor for the metallic coatings of the plate and at the same time permits the use of the rectifier over wide ranges of ambient temperature.

Extremely low ambient temperatures of the order of —40 deg. C. (—40 deg. F.), or lower, are favorable to selenium rectifier operation since they offer a larger margin between temperature of the surrounding air and the maximum safe operating plate temperature.

When the rectifier must operate in ambient temperatures above 35 deg. C., the rectifier power output must be decreased or the size of the rectifier increased so that the sum of internal forward and reverse losses will not raise the plate temperature beyond a maximum of 75 deg. C. Since the reverse losses are a function of the applied a.c. voltage and the forward losses vary with load current, both voltage and current ratings are decreased as the ambient temperature increases towards 75 deg. C. The percentage of decrease in ratings necessary when the ambient temperature exceeds 35 deg. C. is represented in Fig. 6. It will be noted that at 50 deg. C. and 60 deg. C. either of the corresponding pairs of ratings can be used, the choice being determined by economic considerations or the physical dimensions of the respective designs.

The high temperature at which the selenium rectifier can be operated permits many unusual applications, including outdoor use and conditions involving restricted ventilation in close association with equipment generating heat.

An interesting example of extreme temperature operation is afforded by the application of the selenium rectifier to the coaxial cable amplifier. The amplifier is housed in a sealed, non-ventilated metal case which also includes thermionic tubes, transformers and re-

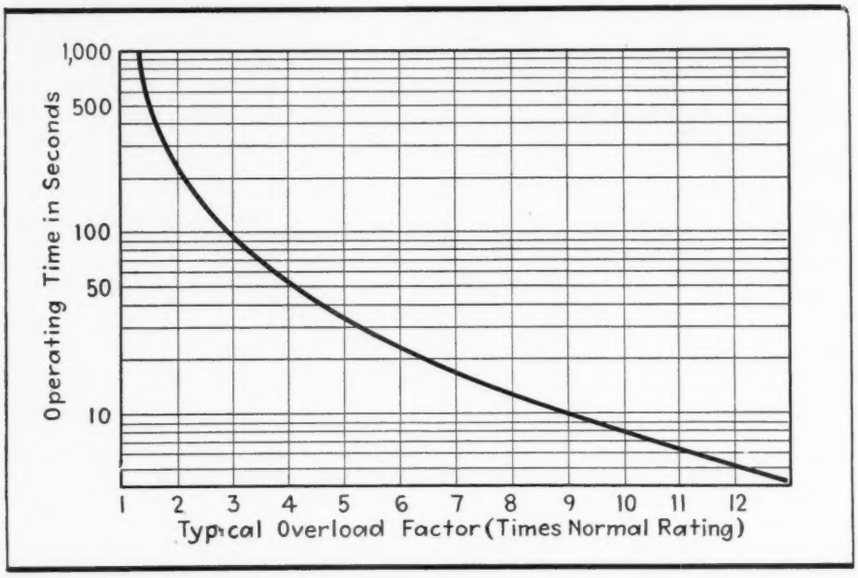


Fig. 8—Typical short period overload capacity of a selenium rectifier. The curve assumes a half-hour period of idleness between operations to allow the rectifier to cool

sistors contributing to the internal temperature rise. Some of these amplifiers are located in manholes, others atop poles where direct rays from the sun add to the internal heat. The rectifier is used for anode supply for the tubes and was designed for continuous operation in ambient temperatures of —40 deg. C. to +68 deg. C. As compared with a mercury vapor rectifier tube for this application the selenium rectifier, in addition to unlimited life, has the advantage that it operates instantly at —40 deg. C. ambient temperature whereas mercury would solidify.

An unusual outdoor application of the selenium rectifier for unattended use is in forced drainage or counter-electrolytic cathodic protection of underground pipe lines, telephone cables, water tanks or other equipment subject to electrolysis. The usual scheme applied to pipe lines is to more than neutralize the e.m.f. generated by the pipe as a primary cell by forcing a larger current between pipe and ground in the direction opposite to the locally generated current. The rectifiers are located along the pipe line at selected intervals; they are mounted on poles which also carry a telephone line, one side of which may serve as an a.c. power conductor with the pipe as a return.

The blocking resistance in the reverse direction decreases with increasing voltage up to the point of breakdown of the barrier layer. Under normal operating conditions the permissible maximum reverse voltage which may be impressed on a single plate is, in most cases, 18 volts r.m.s. for a sinusoidal wave shape or about 25.5 volts peak. When an applied voltage greater than than value is necessary, more than one rectifier plate must be used in a series connection.

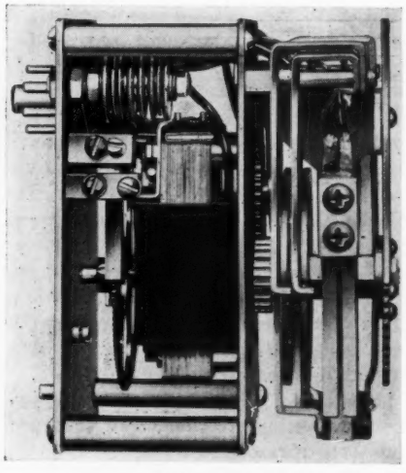
From the foregoing it is evident that the amount of reverse voltage which may be impressed upon selenium rectifier is limited only by the breakdown voltage in the reverse direction. The current output, similarily, is limited only by the maximum permissible plate temperature produced by the combined internal losses of the rectifier plates, largely forward current loss. A current density of about 50 milliamperes per square centimeter is permissible continuously in the forward direction, corresponding to about one volt drop per series plate. For most applications the important design factor is insuring ample margins for operating within the permissible plate temperature limit of +75 deg. C. (determined by power output) down to any low temperature value where the limitation is solely one of voltage regulation.

Since the permissible current output of the selenium rectifier depends entirely upon its ultimate temperature, no theoretical limit can be placed on its current handling capacity. A unit which is initially cool can supply many times its normal continuous current during the time required to bring it to its limiting safe plate temperature. At this point the load must be decreased to a value which does not exceed the normal continuous rating. The relation between load and operating time for a temperature rise of 40 deg. C. is shown in Fig. 8, which applies to cases where there is a sufficient interval between successive load applications to permit the rectifier to cool to its initial temperature of 35 deg. C. If the rectifier is started at a lower temperature, a somewhat longer application of overload is permissible. If the starting temperature is above 35 deg. C., the overload must be decreased in accordance with Fig. 6.

For short operating time, at long intervals, the temperature may not rise appreciably above ambient. Hence choice of a suitable rectifier design is determined by the permissible voltage regulation or at least by the minimum operating voltage required at the load.

It is possible to compute the temperature rise and so design rectifiers for intermittent operation provided the duty cycle can be defined. In cases where the cycle is not recurrent or is too complex to permit ready description, laboratory checks under operating conditions may be required.

In practice, rectifiers are frequently used for intermittent service in elevator operation, alarm equipment and many control circuit applications. For such uses the rectifier has a distinct advantage in that its standby losses are small compared to rotating machines and it is not injured by sudden high overloads which would rapidly destroy thermionic devices dependent upon a heated element to produce an electron stream. Program clock and bell services, such as required for schools, represent an interesting form of intermittent operation. Here the rectifier must operate a number of clocks which are stepped ahead each minute by the application of the rectifier output for perhaps one second per operation as determined by a master clock. At other intervals, which may or may not coincide with the clock operation, vibrating bells may be operated for various lengths of time and single stroke bells operated one or more times. Fig. 9 shows a code transmitter for operating an alarm circuit.



Holtzer-Cabot Electric Company

Fig. 9—Code transmitter used to operate an alarm circuit

SPRING STEELS – III

Data Required for Selection

HAROLD CARLSON
Lee Spring Company, Inc.

CONCLUDING the spring steel series, this article gives up-to-date design data on chromium-vanadium and silicon-manganese spring steels, presented in such a manner that engineers and designers may easily refer to this needed information. Part I of the series (January) explained effects of alloying elements, gave information on wire manufacture and methods for increasing strength and life, and gave specific data on hard-drawn steel spring wire. Design data on music wire and oil-tempered spring steel wire were presented in Part II in February.

Chromium-Vanadium Spring Steel Wire

CHROMIUM-VANADIUM is a good quality, fairly high carbon, alloy spring steel containing small amounts of chromium and vanadium to increase the hardness, tensile strength and fatigue resistance properties.

MANUFACTURE. This steel may be made by the basic or acid, open-hearth or electric-furnace process. Electric is preferred, but acid open-hearth also produces good results. It may be obtained in three conditions as follows:

1. Annealed. In this condition, the steel is fully annealed, formed into the required shapes and then hardened and tempered. Annealed wire is used on all hot coiled springs requiring wire over ⅜ in. thick and for springs using wire over ⅛ in. thick where the ratio of the outside diameter of the spring divided by its wire thickness equals five or less, and for flat leaf springs.

2. Untempered (cold-drawn). In this condition, the wire is not annealed after the last pass through the drawing dies and therefore has the benefit of some cold work. Wire up to ⅜ in. thick may be obtained in this manner, but also requires hardening and tempering.

3. Oil-Tempered. Wire to be oil-tempered is first cold drawn to the desired size from annealed rods and then heated above the critical temperature, quenched in oil and then tempered in a manner somewhat similar to regular oil-tempered carbon steel wire. Variations in the heat-treatment temperatures and drawing time are used to produce the desired hardness and tensile strength. Stock sizes from 0.032 to ½ in. dia. in the W. & M. gage are standard.

APPLICATION. — Chromium - vanadium steel is recommended for springs subjected to shocks by impact or suddenly applied loads and where long fatigue life is essential. Springs made from this steel successfully withstand stresses higher than those that may be imposed upon oil-tempered carbon steel, but not as high as music wire. This steel is often specified for coil springs and flat leaf springs used on the trucks of railroad cars, trolley cars and buses, and for motor valve springs and die springs. For all coil springs made of round wire from 0.032 to ½ in. dia. the oil-tempered condition should be specified provided the outside diameter of the spring divided by the wire diameter exceeds five. Square, rectangular, and round wire rolled into rectangular shape and round edges may be obtained in the annealed or untempered conditions, and in the oil-tempered condition on special order. Flat, hot rolled steel is adaptable for flat-leaf or laminated elliptical springs. Springs made from this steel may be used in temperatures up to 400 deg. F. with less than 5 deg. loss of load if

Table XII—Composition of Chromium-Vanadium Spring Wire

(A)—S.A.E. SPECIFICATIONS
(Percent)

Composition	Tempered or Annealed for Cold Coiled Springs		Hot Coiled Springs S.A.E. 6160 Special
	S.A.E. 6145	S.A.E. 6150	
Carbon	0.40–0.50	0.45–0.55	0.55–0.65
Manganese	0.60–0.90	0.60–0.90	0.50–0.80
Chromium	0.80–1.10	0.80–1.10	0.80–1.10
Vanadium	0.18 Desired*	0.18 Desired*	0.15–0.20
Silicon	**	**	**
Phosphorus	0.040 Max.	0.040 Max.	0.040 Max.
Sulphur	0.050 Max.	0.050 Max.	0.040 Max.

(B)—A.S.T.M. SPECIFICATIONS
(Percent)

Composition	Hot Coiled Springs, A.S.T.M. A60–39	Cold Coiled Springs, A.S.T.M. A231–41	Valve Spring Wire, A.S.T.M. A232–41
Carbon	0.50–0.60	0.45–0.55	0.45–0.55
Manganese	0.60–0.90	0.60–0.90	0.60–0.90
Chromium	0.90–1.10	0.80–1.10	0.80–1.10
Vanadium	0.18 Desired*	0.18 Desired*	0.15–0.25
Silicon	.....	0.15–0.30	0.12–0.30
Phosphorus	0.045 Max.	0.040 Max.	0.030 Max.
Sulphur	0.045 Max.	0.050 Max.	0.030 Max.

*0.15 percent minimum.
**The silicon range of all S.A.E. basic open-hearth alloy steels is 0.16 to 0.30 percent; for electric and acid open-hearth alloy steels it is 0.15 percent minimum.

stressed under 70,000 lb. per sq.in. and heated after coiling to 700 deg. F.

Some investigators of fatigue life characteristics of chromium-vanadium springs have noticed that an occasional spring breakage occurs prematurely due to imperfections in the steel. This appears inevitable in every test of a large quantity of springs but should not deter the specifying of this steel or cause a pessimistic viewpoint on the outlook or use of this material. Two or three springs out of a hundred may break early but if the remainder withstand a high number of deflections without fracture, the few that did break should not be included in the fatigue life characteristics in a manner to lower such values.

Table XIII—Tensile Strength of Chromium-Vanadium Wire

Wire Dia., In.	Tensile Strength, Minimum	Lb. per sq., in., Maximum
0.035	280,000	300,000
0.041	270,000	290,000
0.047	270,000	290,000
0.054	265,000	285,000
0.063	265,000	285,000
0.072	260,000	280,000
0.080	255,000	275,000
0.092	250,000	270,000
0.105	250,000	270,000
0.120	245,000	265,000
0.135	240,000	260,000
0.148	235,000	255,000
0.162	230,000	250,000
0.177	225,000	245,000
0.192	220,000	240,000
0.207	215,000	235,000
0.244	215,000	235,000
0.283	210,000	230,000
3/8 in. and up	200,000	220,000

CHEMICAL COMPOSITIONS. There are many standard specifications in existence for this material. Upon close examination of Table XII, it will be seen that many overlap one another. The one most generally known, most popular, produced more often and in larger quantities with better uniformity, and recommended for all chromium-vanadium springs with wire up to ½ in. dia. or thickness, is S.A.E. 6150. For hot coiled springs, either S.A.E. 6160 or A.S.T.M. A60-39 may be specified. Valve spring wire in accordance with A.S.T.M. A232-41 is similar to S.A.E. 6150 except that it is a wire with a very smooth finish obtained by heat-treatment in a controlled atmosphere furnace. When purchasing any of these steels it is necessary to state whether it is annealed, cold-drawn, or oil-tempered.

TENSILE STRENGTH. The tensile strength of oil-tempered chromium-vanadium is given in Table XIII. For springs made from annealed or untempered wire the same properties will be obtained after heat-treatment.

PHYSICAL PROPERTIES of chromium-vanadium wire are listed in Table XIV. Oil-tempered chromium-vanadium wire up to ¼ in. dia. may be bent around a mandrel equal to its own diameter without breaking or cracking the surface. Wire above ¼ in. dia. will bend over a diameter equal to twice the wire diameter.

TOLERANCES. Cold drawn and oil-tempered wire may, when necessary, be obtained with small tolerances on the wire diameter. One manufacturer furnishes material in accordance with tolerances shown in Table XV (A). Table XV (B), for the same wire, and Table XV (C) for annealed wire used for hot coiled springs, are similar to A.S.T.M. standards, but permit too much leeway for exacting work. Any out-of-roundness should always be within one-half of the total wire diameter tolerances.

Table XV—Chromium-Vanadium Wire Tolerances

Wire Dia., In.	Tolerance
(A)—OIL-TEMPERED (MANUFACTURER'S)	
Up to 0.062	0.0005
0.063 to 0.135	0.00075
0.136 to 0.250	0.001
0.251 and up	0.0015
(B)—OIL-TEMPERED	
0.028 to 0.072	0.001
0.073 to 0.375	0.002
0.376 and up	0.003
(C)—HOT-ROLLED ANNEALED	
Up to 5/16	0.005
Over 5/16 to 7/16	0.006
Over 7/16 to 5/8	0.007
Over 5/8 to 7/8	0.008
Over 7/8 to 1	0.009
Over 1 to 1 1/8	0.010

PRICE. An average price in 1940, for S.A.E. 6150 in sizes up to ½ in. dia. in the annealed, cold drawn, or oil-tempered condition, in quantities of 50 to 100 lb. ran from 20 to 25 cents lb.

HEAT-TREATMENT. Springs made from oil-tempered chromium-vanadium wire are usually heated after coiled from 500 to 600 deg. F. to relieve coiling stresses. For use in elevated temperatures they should be heated to 700 deg. F. If made from annealed steel (or untempered) they should be heated to from 1,550 to 1,650 deg. F. (1,600 deg. preferred), quenched in oil and tempered at 675 to 875 deg. F. Extension springs wound with initial tension will lose from 25 to 50 percent of their initial tension when heated to 500 deg. F. after coiling.

Table XIV—Physical Properties of Chromium-Vanadium Wire

Elastic Limit in Tension: Percent of Tensile Strength	88 to 93 percent
Elastic Limit in Torsion: Percent of Tensile Strength	65 to 75 percent
Modulus of Elasticity in Tension, *E*	29,000,000–30,000,000
Modulus of Elasticity in Torsion, *G*	11,200,000
Hardness, Rockwell *C* min. and max	42–50
Weight, lb. per cu. in	0.284 lb.
Elongation in 2 in	10–14 percent

Silicon-Manganese Spring Steel

SILICON-MANGANESE SPRING STEEL is similar to the regular high-carbon spring steels except that it has a higher percentage of silicon. It is generally used in the form of hot-rolled annealed rods, bars, and rectangular flats, for springs hardened and tempered after forming. It cannot be rightfully designated as an alloy steel nor as a special steel as its composition contains the

Table XVI—Physical Properties of Silicon-Manganese Spring Steels

Elastic Limit in Tension: Percent of Tensile Strength	70 to 80 percent
Elastic Limit in Torsion: Percent of Tensile Strength	60 to 70 percent
Modulus of Elasticity in Tension, *E*	29,000,000
Modulus of Elasticity in Torsion, *G*	10,750,000
Hardness, Rockwell *C*—after heat-treatment	42 to 46
Weight, lb. per cu. in	0.284 lb.
Elongation in 2 in., approx	9 to 12 percent

same elements as any straight carbon steel. Its infrequent use when compared to other spring-steels generally places it in the category of special spring steels. Its color is a dull, bluish-black with a slight tinge of gray.

MANUFACTURE. This steel is made by one or more of the following processes: electric-furnace, open-hearth, or crucible, either basic or acid, but basic-electric-furnace steel is preferred. It is generally hot-rolled and furnished in the annealed condition. Its tensile strength and hardness are obtained by heat-treatment after forming into the desired spring shape.

APPLICATION. Silicon-manganese is used principally in flat, rectangular sections as leafs in elliptical springs for railroad cars, trolley cars, trucks and buses. Round sections above 3/8 in., coiled into helical springs, are also used for these applications. The first springs used in the so-called "knee action" of motor cars were made from S.A.E. 9260 silicon-manganese hot rolled, annealed, centerless ground, 3/4 in. dia. steel bars, and proved satisfactory. This steel in round sections is seldom used in sizes less than 3/8 in. dia. and is recommended only for hot-rolled springs, hardened and tempered after forming, and then only when chromium-vanadium or high-carbon steels are either too difficult to obtain or are too expensive.

CHEMICAL COMPOSITIONS. S.A.E. 9260 is most commonly known and most frequently used; it will be seen in Table XVIII, however, that A.S.T.M. A-59-39 has practically the same composition as S.A.E. 9260.

TENSILE STRENGTH. Reliable results of accurate tests to determine the tensile strength over a wide range of wire diameters are not available. Values in Table XVII are an average made from data received from several sources and are believed to be sufficiently accurate to act as a general guide for all compositions.

Table XVII—Tensile Strength of Silicon-Manganese Steel

Wire Dia., in.	*Tensile Strength lb. per sq. in.
Under 3/4	225,000 to 250,000
Over 3/4	210,000 to 225,000

*After heat-treatment.

PRICE. Its cost per pound is so variable due to the limited quantities purchased and because of its infrequent demand, that only a general approximation may be made which is: cost per pound, in lots of 100 lb. for round stock in 1940 was about 75 percent as much as chromium-vanadium. In flat stock, it costs only a trifle more than ordinary flat hot-rolled spring steel.

GENERAL NOTE. Although silicon-manganese steel has acquired a definite place as a spring material, its use in general should be limited to the field of flat, rectangular leaf or elliptic springs; for when used in round sections, it cannot be favorably compared with chromium-vanadium. The curves and data in Fig. 3, reproduced with permission of the Vanadium Corporation of America, compare the permanent set during the life of chromium-vanadium and silicon-manganese spring steels.

Table XVIII—Composition of Silicon-Manganese Spring Steels

(Percent)

Composition	S.A.E. 9255	S.A.E. 9260	A.S.T.M. A59–39	Special No. 1
Carbon	0.50–0.60	0.55–0.65	0.55–0.65	0.53–0.63
Manganese	0.60–0.90	0.60–0.90	0.60–0.90	0.75–0.95
Silicon	1.80–2.20	1.80–2.20	1.80–2.20	1.85–2.05
Phosphorus	0.040 Max.	0.040 Max.	0.045 Max.	0.040 Max.
Sulphur	0.050 Max.	0.050 Max.	0.045 Max.	0.040 Max.

Table XIX—Silicon-Manganese Spring Steel Tolerances

(Hot rolled, annealed steel)

(A)—ON DIAMETERS OR SIDE OF SQUARE

Size, In.	Plus or Minus, In.
5/16 and under	0.005
Over 5/16 to 7/16	0.006
Over 7/16 to 5/8	0.007
Over 5/8 to 7/8	0.008
Over 7/8 to 1	0.009
Over 1 to 1 1/8	0.010
Over 1 1/8 to 1 1/4	0.011
Over 1 1/4 to 1 3/8	0.012
Over 1 3/8 to 1 1/2	0.014
Over 1 1/2 to 2	1/64

(B)—ON THICKNESS OF ROUND-EDGE FLATS

Thickness, In.	Tolerance on thickness is plus or minus and depends on width			
	2 in. wide and under	Over 2 in. to 4 in.	Over 4 in. to 6 in.	Over 6 in. to 8 in.
3/8 and under	0.008	0.010	0.010	0.012
Over 3/8 to 5/8	0.012	0.012	0.012	0.015
Over 5/8 to 1	.....	.....	0.015	0.020

(C)—ON WIDTH OF ROUND-EDGE FLATS

Width, In.	Plus or Minus, In.
2 and under	1/64
Over 2 to 4	1/32
Over 4 to 6	3/64
Over 6 to 8	3/32

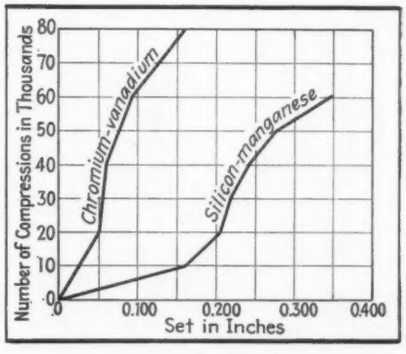


Fig. 3—Life comparison of chromium-vanadium with silicon-manganese spring steels, based on set

AUTOMATIC OILERS

AUTOMATIC OILERS meet a wide variety of lubrication requirements as well as accomplishing their primary objective of avoiding constant vigil over operating machinery. The simplest and most economical oilers do not go beyond the latter requirement. Others, however, meet such requirements as maintaining constant oil level in bearings or having an air return connection for pressure equalization and oil cleanliness. Needle valves with accurate adjustment and shut offs give exact feed regulation and conserve oil when machines are not operating. Some are equipped with oil filters. Automatic heat regulation of oil flow is employed in still others or wick feeds if these are preferred. Many now have transparent unbreakable plastic reservoirs instead of glass. Designs shown are by courtesy of Trico Fuse Mfg. Company, Gits Brothers Mfg. Company and the Alemite Div., Stewart-Warner Corp.

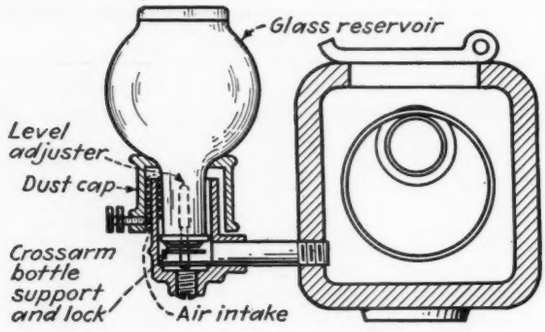


FIG. 1- Automatically maintains oil level

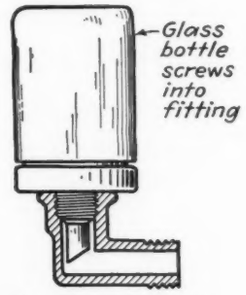
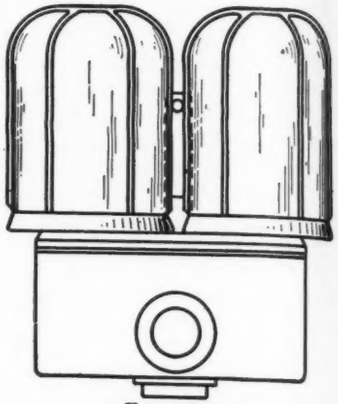


FIG. 2- Simplest constant level oiler



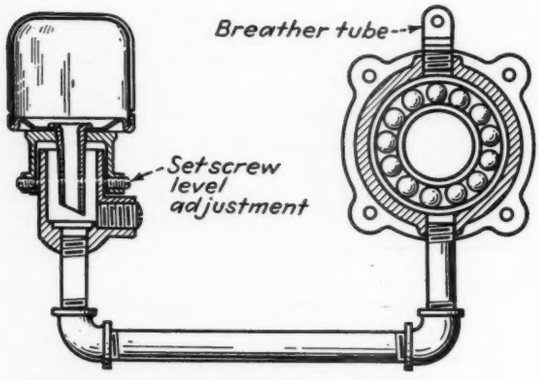


FIG. 3- Un breakable constant level oiler

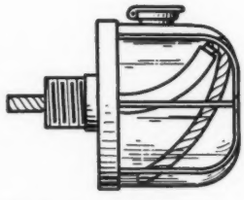


FIG. 4- Side mounting wick-feed oiler without sight feed

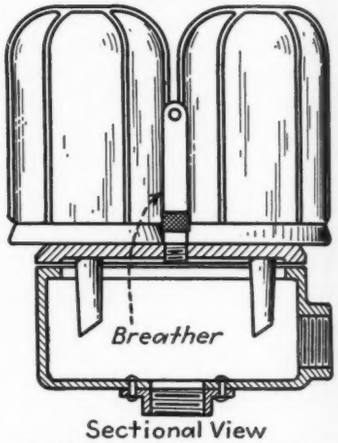


FIG. 5- Lower reservoir allows use of two to six 8-oz. bottles at one point

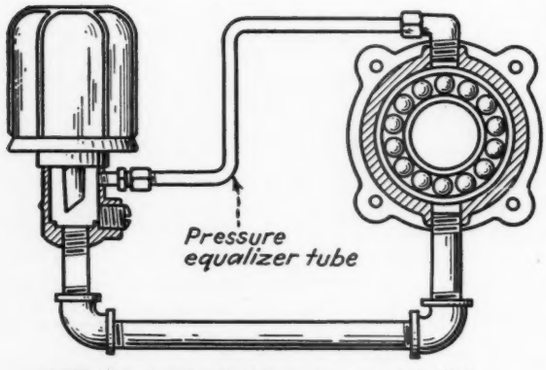


FIG. 6- Installation to avoid dirt and equalize pressure

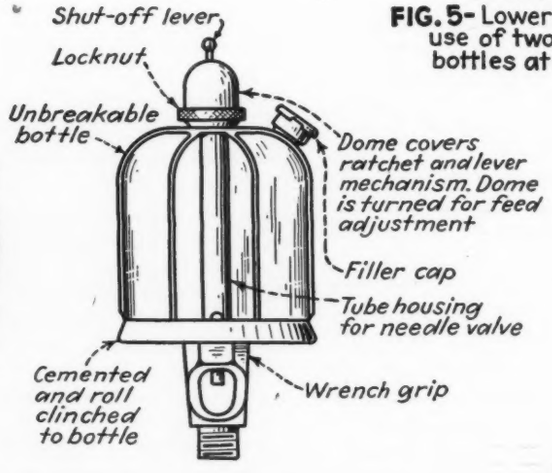

Shut-off lever
Locknut
Unbreakable bottle
Dome covers ratchet and lever mechanism. Dome is turned for feed adjustment
Filler cap
Tube housing for needle valve
Wrench grip
Cemented and roll clinched to bottle

FIG. 7- Gravity feed oiler with needle-valve adjustment

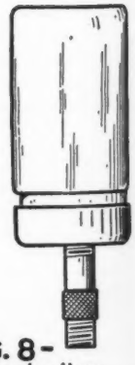


FIG. 8- Thermal oiler holding 3/4 to 1½ oz.

FIT ALL NEEDS

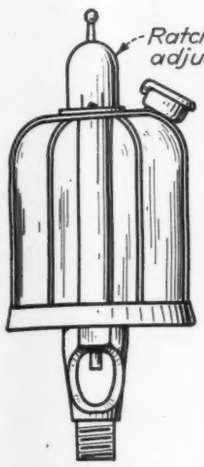


FIG. 9 - Gravity feed oiler with ratchet feed adjustment

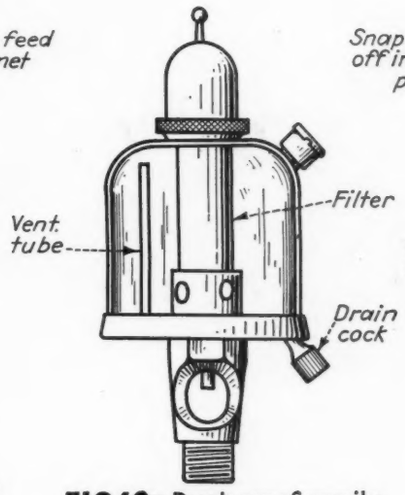


FIG. 10 - Dust-proof gravity oiler with drain cock

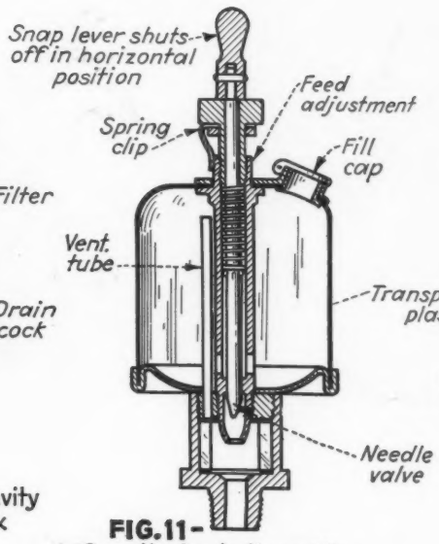


FIG. 11 - Gravity feed oiler with needle valve adjustment

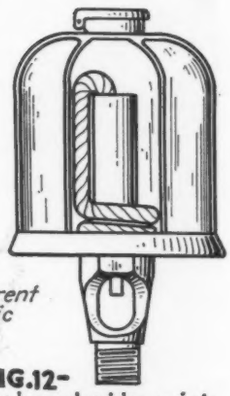


FIG. 12 - Unbreakable wick feed oiler

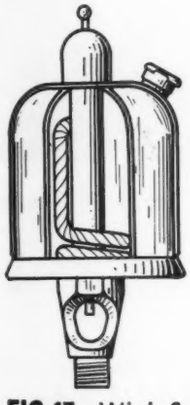


FIG. 13 - Wick feed oiler with shut-off lever

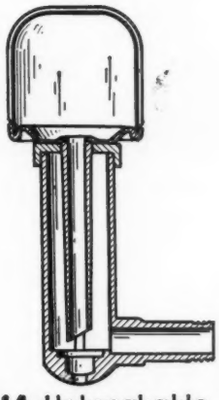


FIG. 14 - Unbreakable, unadjustable constant level oiler with high surge level

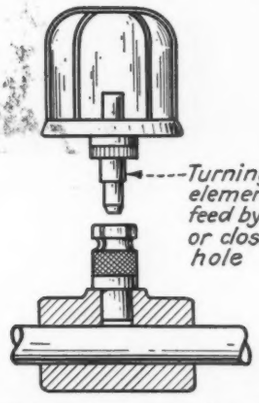


FIG. 15 - Thermal oilers depend on bearing heat for feed regulation

FIG. 16 Gravity feed oiler with knob adjustments and shut-off

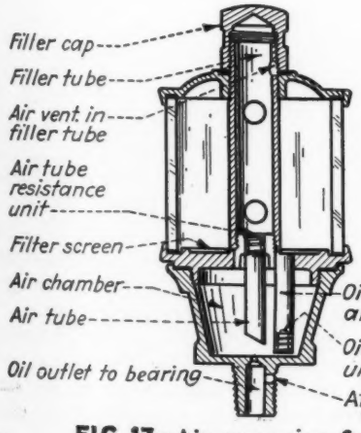


FIG. 17 - Air expansion from bearing heat operates oiler

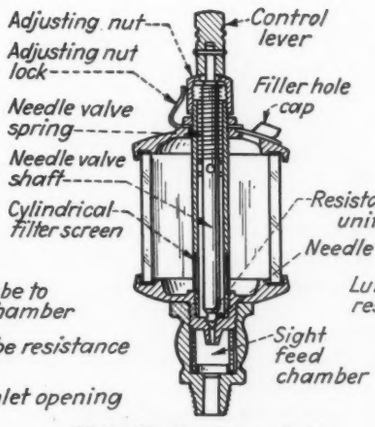


FIG. 18 - Designed for fine adjustments

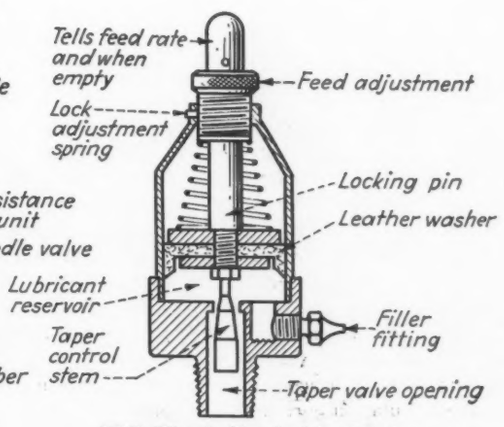


FIG. 19 - Adjustable feed controls flow rate

Fig. 1—Synthetic resin varnish applied to deep wound coils. Penetration to any depth can be obtained, and drying is complete

SYNTHETIC RESIN VARNISH

Advantages for Coil Insulation

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Research Engineer
GRAHAM LEE MOSES
Insulation Engineer
Westinghouse Electric & Manufacturing Company

NEARLY all forms of electrical insulation require the use of varnish or similar compound to improve their insulating characteristics. Cotton, paper, asbestos, fibrous glass and mica insulating materials, all have their insulating characteristics improved greatly when the interstices are filled with varnish and the surface fortified with a satisfactory varnish film. Suitable varnish treatment of insulation is of particular importance on apparatus subjected to excessive humidity, corrosive agents, oil and high temperatures. In addition, varnish treatment may improve the mechanical strength of insulation by binding it together and anchoring it to the supporting structure. Where it is flexible, varnish treatment may provide protection to insulation for long periods even when it is subjected to vibration and repeated expansion and contraction.

On railway motors and generators, mining locomotive motors, and many forms of industrial motors, varnish protection is essential because of the unusually severe duty and exposure to dirt, dust, moisture, and oil. On other equipment, such as central station generating apparatus and auxiliaries, which are not ordinarily exposed to these hazards, varnish treatment is important because it furnishes insurance against service interruptions when such exposure may occasionally occur.

Because of the importance of varnish protection to electrical insulation, continuous development work on the subject is done by manufacturers of electrical equipment. One phase of this work was the development of labora-

tory tests which interpret the service requirements. Only by having such tests can laboratory results be correlated with field experience.

Desirable characteristics normally expected in varnishes are:

(a) Moisture resistance
(b) Oil resistance
(c) Resistance to weak acids and alkalis
(d) Dielectric strength
(e) Insulation resistance
(f) Flexibility
(g) Heat flexibility endurance (often referred to as "life").

It is important that varnishes have high initial values for characteristics (a) to (f), but, it is of greater importance that these values are maintained at the required level throughout the useful life of the machine. Varnishes with high initial values of essential characteristics may be less desirable than other varnishes with lower initial values if the latter age more slowly. Thus, life may be considered the ability to maintain essential insulating qualities under specific conditions of aging. To determine the effect of temperature on the flexing life of varnish films the A.S.T.M. heat endurance test was extended to temperatures above the conventional 105–110 deg. C. This test evaluates the physical flexing life of varnish films on copper as determined by visual observation. It is normally taken at only one temperature. Fig. 2 shows the results of such tests on several varnishes. From these data it can be seen that varnishes differ greatly in relative flexing life and that flexing life of all varnishes is greatly affected by changes in operating temperature.

A special test was developed to measure electrically the result of aging varnish films at different temperatures, at the same time checking their moisture resistance. This consisted of coating carefully prepared U-shaped copper rods with a controlled thickness of varnish film. The U test pieces were immersed in water and their insulation resistance measured at 500 volts. Test pieces were then placed in ovens and baked at 150, 175, or 200 deg. C. They were removed periodically and insulation resistance of the varnish film in water measured. It was found that the insulation resistance falls gradually for a considerable period but finally "nose dives" toward zero, as illustrated in Fig. 3. The period during which the decrease in insulation resistance was relatively gradual was taken as the useful life of the varnish film. Curve Fig. 5 shows the relative lives of various varnishes at different temperatures as determined by the U piece test.

After the electrical failure of the varnish film, the samples were returned to the oven for additional baking until the film failed visibly and flaked away from the copper. The combination of the electrical and physical test of varnish films on U pieces gave an indication of the relative life of varnish films under the static conditions whereas the A.S.T.M. life test is a flexing heat endurance test.

By means of these tests in addition to standardized varnish tests, it was found possible to evaluate moisture resistance and life under static flexing conditions for various varnishes. These new tests proved of value in the devel-

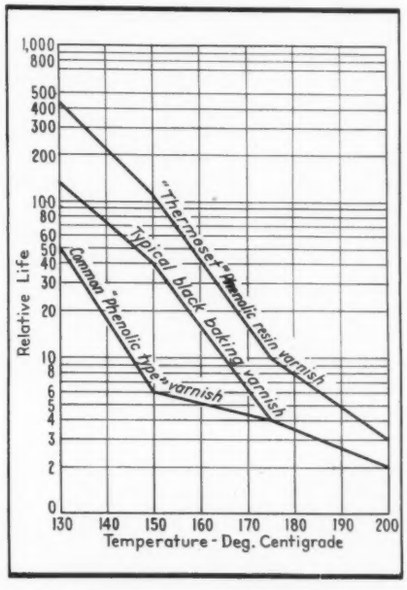


Fig. 2—Effect of temperature on flexing life of varnishes determined by A.S.T.M. heat tests at elevated temperatures

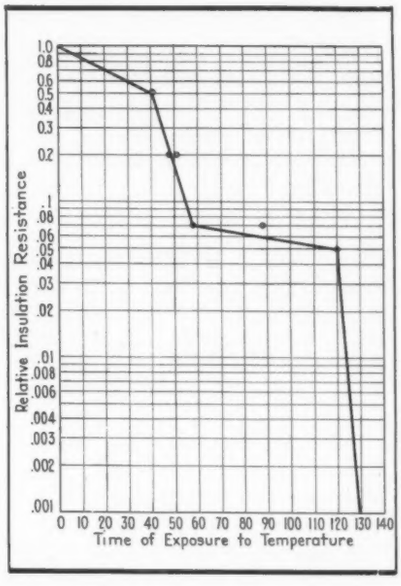
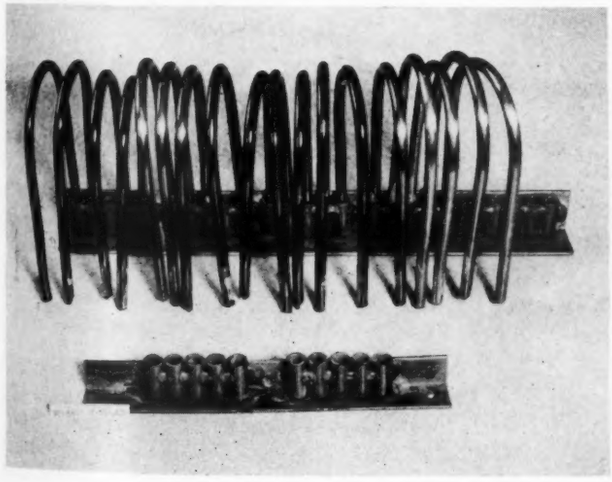


Fig. 3—Effect of temperature on static life of varnishes as determined by special U piece test



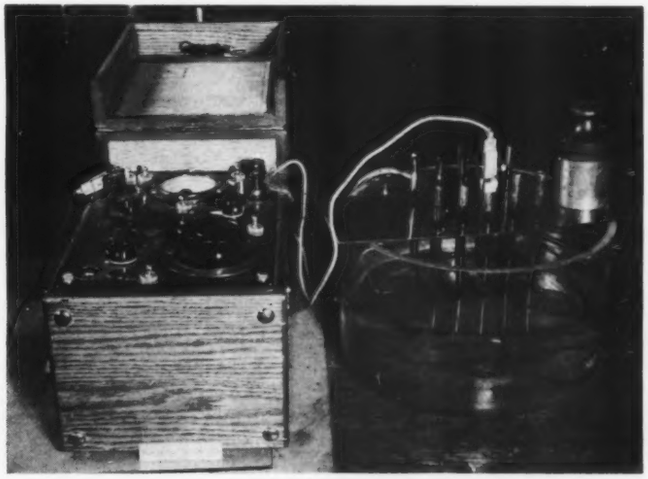


Fig. 4—(Left) U-shaped copper rods coated, before immersion in water. (Right) Testing insulation resistance

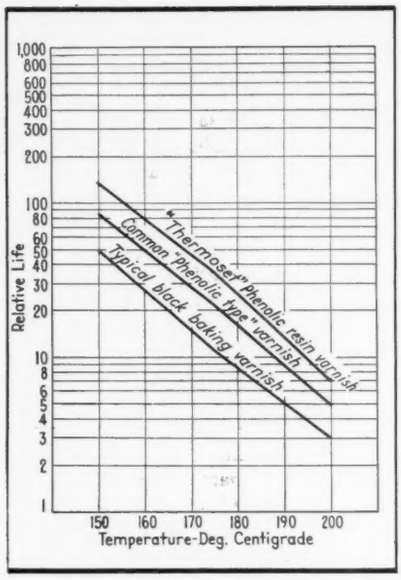


Fig. 5—Relative lives of varnishes at different temperatures show value of synthetic resin type

opment of new heat-resisting varnishes of the synthetic resin type to meet a distinct need in transportation service. These varnishes have been proved by test to have the excellent moisture resistance and long life so essential in this field and good insulation characteristics as well as several desirable processing characteristics.

Curing by polymerization (heat reaction) rather than by oxidation, they dry completely even in thick films and deep-seated parts of coils and windings. Once varnish has "set-up" it does not re-soften in service. Initial dips or impregnation need not be thoroughly cured out as the final bakes will complete the cure of the earlier treatments at the same time the final treatment is cured. This curing characteristic is of great importance in the production of high quality windings. It permits the use of partially cured oils so that they can be wound while in a flexible state. The complete cure of the varnish in the deep seated parts of the winding can then be accomplished by the final bake when the last treatments are applied. This is of importance in rewinding old apparatus as well as aiding in the manufacture of new apparatus.

One interesting and important test simulating field conditions was used for checking the water resistance of the synthetic resin varnish. In this a three weeks "shower bath" was used in testing street car motor stators. The new varnish was compared directly with conventional black baking varnish treatment on standard motors. Field coils were impregnated in both cases and both coils and assembled stators were given two dips and bakes. Initial insulation resistance was measured by an electronic megohm bridge. Then the stators were sprayed with a fine mist of water throughout each day. The spray was turned off over night and the coils left standing with the water on them. Insulation resistance data was taken every morning and night, one minute after application of voltage. Coils treated with synthetic resin varnish had somewhat higher initial resistance than coils treated with standard varnish. However, after the spray test the coils treated with this varnish had 4 to 5 times the resistance of coils with standard treatment.

The penetrating characteristics of thermo-setting varnishes are such that good treatment of insulation is obtained when dipping unheated coils or wound apparatus in the varnish at room temperature.

One important characteristic of the new varnish is that it can be used for pressure impregnation at high body with low solvent content. Thus, excellently filled coil voids and interstices can be obtained. This property coupled with good cement power produces a sturdy, solid coil construction. Result is a stronger and more compact winding, thereby minimizing the destructive effect of vibration. It also provides and retains better paths for heat flow from within the coil to the heat dissipating surfaces.

The following tabulation summarizes the characteristics of the synthetic resin thermo-setting varnishes:

(1) Excellent moisture resistance in comparison with other varnishes.

(2) Good dielectric strength, both dry and wet.

(3) Highly oil resistant.

(4) Good resistance to weak acids and alkalis.

(5) By both static and flexing tests shows maintenance of all necessary insulating qualities for long periods.

(6) Dries throughout by baking and will not resoften when heated.

(7) Penetrates insulation and coil capillary openings very readily.

(8) Fills voids better than most varnishes.

(9) Produces a tough, resilient protective surface film with solid internal structure.

(10) Cures at reasonable baking temperature.

(11) Withstands high-temperature operation well.

The development of fibrous glass insulation a few years ago made it clear that the ordinary types of organic varnishes were the new bottleneck to high-temperature insulation development. This need spurred the development of the new synthetic resin varnishes which has proved to be a distinct forward step in the insulation of electrical machinery, particularly where Class B insulation is required.

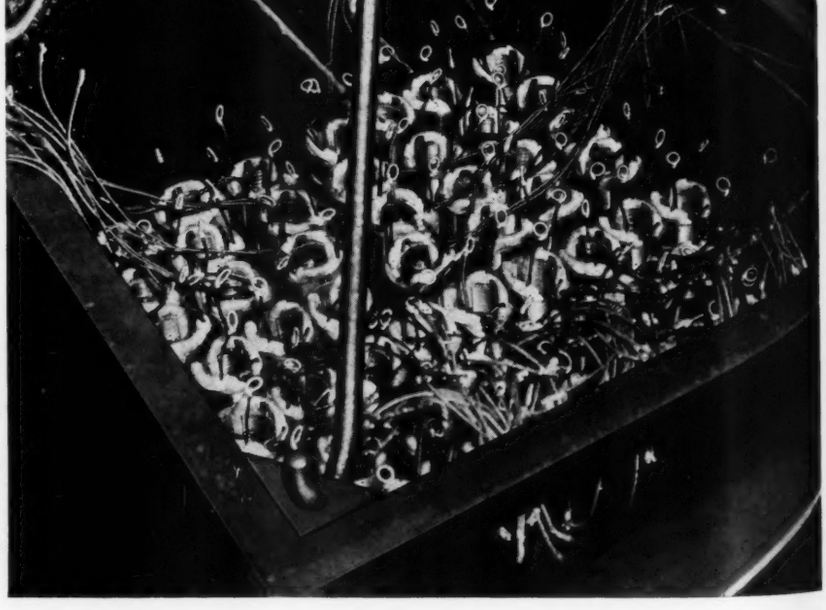
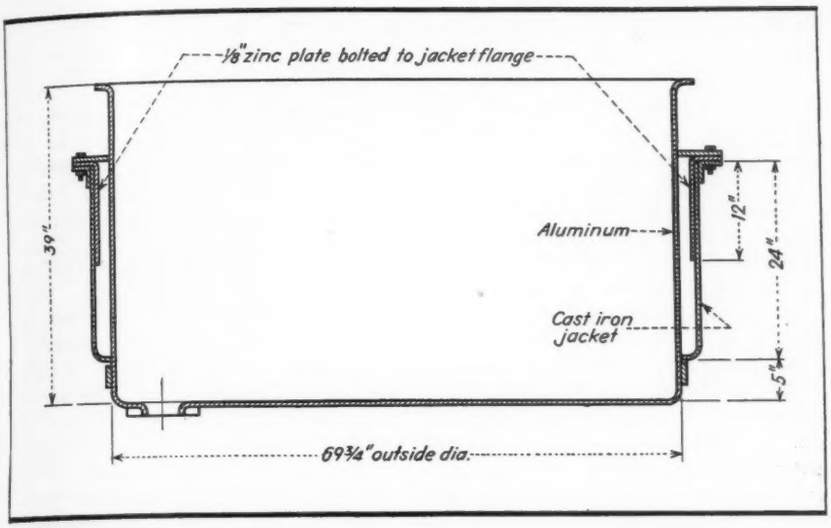


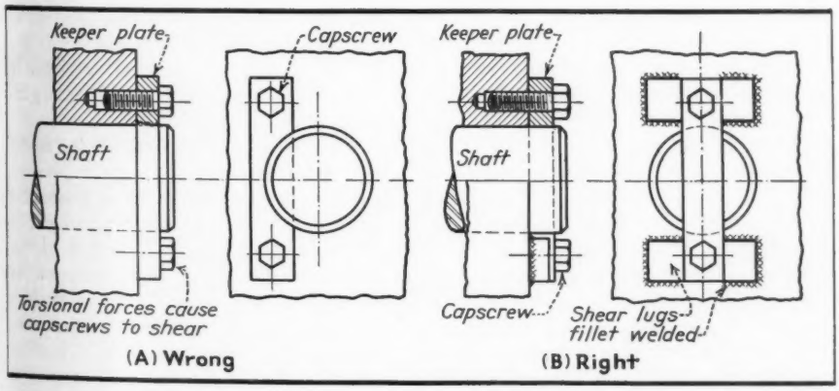
Fig. 6—High-speed, small motor stators emerge from first dip in thermo-setting varnish

Causes and Cures

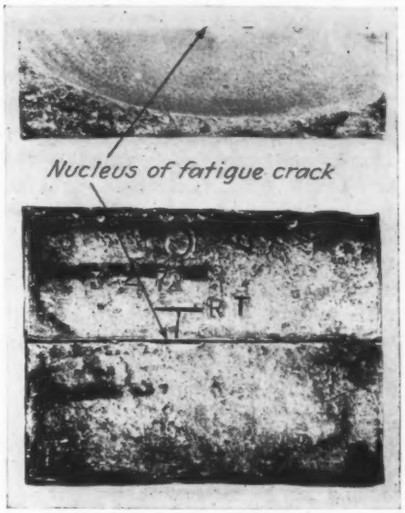


Aluminum equipment, inert to most organic chemicals and many inorganic chemicals, is sometimes attacked by waters used for heating or cooling. Example is this iron-jacketed recrystallizing tank made of 99.7 percent pure aluminum to resist corrosive action of tartaric acid. Cooling water contained some iron oxides, and aluminum was attacked by galvanic corrosion. Cure of this and similar cases is cathodic protection with zinc. Contrary to conclusions drawn from electromotive series, zinc in contact with aluminum in many solutions is anodic; the aluminum being cathodic. Hence zinc is attacked, not aluminum. Applying this theory to tank, sheet of zinc about 0.020 in. thick was wrapped around tank wall. This was unsatisfactory, since the zinc corroded sufficiently to prevent good electrical contact. Satisfactory results were finally obtained by attaching ⅛-in. plates inside the water jacket as shown. These will last 4 to 5 years before they need replacement.

Research reported by Dr. R. B. Mears and H. J. Fahrney in the 1941 A.I. Ch. E. *Transactions* indicates that cathodic protection is most successful in neutral or slightly acid solutions, and probably will not be good in alkaline solutions.



Keeper plate for a pin in a heavy machine was improperly designed as shown in (A). There was a strong tendency for the pin to rotate, and this soon sheared one of the retaining screws on the keeper plate, allowing the pin to rotate, roll over the edge of the keeper plate keyway, and pull out. Proper design is shown in (B), wherein shear stresses caused by rotational forces are taken by welded lugs instead of retaining screws.



Chisel-marked letter "H" was starting point of fatigue cracks that led to failure of this rectangular section forging. Nucleus is near middle of face and it had progressed until most of cross-section had developed finely fractured surface of fatigue crack. Section is 1¼ x 5 in., approximately. It would be hard to predict a fatigue crack starting from a stamped letter in such a position. Best cure is to stamp marks in non-stressed areas.

WINDINGS OF SMALL RELAYS were found to be corroding in contact with the wax-impregnated paper used as interleaving material. Windings were 36-ga. copper wire. Cure was to substitute sheet cellulose acetate for waxed paper. Elimination of corrision design factor permits finer wire (special 40 ga.), more ampere-turns per inch of wire, and sealing the interleaving sheets to spool heads with acetone-base cement. This also locks lead-out wires in position.

LARGE INCLOSURES for switchgear had to be bonderized before assembly by welding because dipping equipment in the shop was not large enough to handle the assembled housings. The welding operation destroyed the bonderized surfaces around the joints, making a very poor paint base, and leading to finish failures. Solution: facilities large enough to dip complete inclosures.

PRODUCT ENGINEERING will pay a minimum of $3 for each example published in Causes and Cures. Where illustrations are necessary, include drawings, rough sketches or photographs.

PATENT PROCEDURE – III

The Why And How of Preliminary Investigations

MILES HENNINGER
Patent Department, Allis-Chalmers Manufacturing Company

REVISED Statutes Section 4886 in part is as follows: "Any person who has invented * * * any new * * * art, machine, manufacture or composition of matter * * * not known or used by others in this country * * * and not patented or described in any printed publication * * * more than one year prior to his application, and not in public use or on sale in this country for more than one year prior to his application, * * * may obtain a patent therefore."

The statute says "any person" which means any natural person capable of making any invention. Mere legal persons such as associations or corporations can make inventions only via human agents and may receive patents only by assignment from such agents. The point of the competent age of a person by whom and at which an invention can be made has never been raised in spite of the fact that an application is made under oath and an oath can be taken only by a competent person. If the point were ever raised, it is believed that any court would hold any person capable of making an invention also competent to make the oath. It is well known that an administrator or executor or a guardian may take the oath for a deceased inventor or an inventor who has become insane. The law will not deprive any one nor his heirs nor assigns of a patent for an invention of which his inventorship can be established. Therefore even if you die or go insane, your previously made and properly recorded invention lives after you for the eventual benefit of the public.

Making of a contract to assign any future invention is current practice and, of course, immediately transfers all rights to such inventions from the inventor to the other contracting party. Such contracts, unless invalid under the law of contracts, are enforceable and an inventor can be required to execute all papers necessary to make the application and to make a proper transfer of the invention. Transfer of inventions will be considered in more detail later in connection with the employer-employee relationship.

Loss of invention by conduct may be either voluntary or involuntary and may occur either before or after filing an application thereon. An inventor may abandon or dedicate his invention to the public by a voluntary statement in express words at any time. But the conduct by which an invention may be involuntarily lost must be very clear and well proven. If an inventor conceals his invention until spurred into activity by a rival or if the invention is held as a trade secret for an indefinite time, the inventor is held to have abandoned the invention. Also, a patent will be refused the inventor if he has patented the invention in a foreign country or otherwise had printed and published a description of his invention, in such terms as to enable another person to practice the invention, for more than one year before a U. S. application is filed, and the inventor will be refused a patent if he has placed specimens of the invention in public use or on sale more than one year before a U. S. application is filed. The one year publication or public use bars to a patent are wholly within the inventor's control and he is held strictly accountable for them.

After the application is filed, the examiner may finally reject all claims for any one of several reasons. If the inventor acquiesces in such final rejection without appeal or if he loses an appeal, the application is abandoned and cannot be renewed.

Present day conditions again bring into effect the statute relating to war orders of secrecy and also the various presidential orders regarding foreign publication of restricted information. Inventions may be kept secret and grant of the patent withheld until the end of the war. Publication of the invention or filing an application in a foreign country after such order, may cause the invention to be held abandoned. Under presidential proclamation No. 2465 of March 5, 1941, it is necessary to obtain a license before filing, in a foreign country, any application or any amendment to an application dealing with restricted material.

Notice that R. S. 4886 above says "* * * any new * * * art * * *." The first step in determining whether or not a patent application is to be filed, assuming that the invention produces a useful result, is to determine its newness or novelty. Assuming further that the invention is as yet merely a mental concept of the result to be accomplished with only vague ideas of the mechanism to be used and has not been put into public use or on sale in the United States, novelty depends on whether the invention was known to others and whether such knowledge is a matter of printed record. The printed record may be a patent of any country or any other printed publication. As stated in the first article, the primary field of search is the United States and foreign patents. Fig. 7 shows the classification for incandescent electric lamps. Other devices are similarly classified, thus providing an index to United States patents which make the 2¼ million of U. S. patents readily accessible. If a considerable amount of development of the invention is contemplated, it is advisable to extend the search to textbooks, trade periodicals, technical society publications, catalogs and other advertising of manufacturers of similar devices, if any, and generally to locate all material, both old and current, bearing on the problem to be solved or on the structure invented to solve the problem. The thoroughness of the search will be governed by the time and money to be expended in developing the invention. Up to 5 percent of such contemplated expenditure is believed to be an entirely reasonable amount to spend for the preliminary investigation of novelty.

One of the easiest methods for securing information as to prior devices similar to your invention is to inspect similar devices on sale and which, if patented, will bear a patent marking. The advertising of manufacturers or discussions with manufacturers of similar articles will yield information concerning the art generally. Having secured names of manufacturers or other inventors of similar devices, one may use each annual Index of U. S. Patents to find all patents assigned to or issued to any one of the manufacturers or inventors during a given year. The brief of such patents in recent Official Gazettes will show the class

and subclass in which the patents are placed. The annual Indexes of U. S. Patents and Gazettes are to be found in libraries in approximately 70 cities in the United States. Another list in the Index gives all patents arranged according to subject matter and will yield more patent identifications. The inventor may continue search through the Indexes from year to year or, once having definitely established the classification of the pertinent patents, may order the entire subclass.

If any particular patent is very close to the invention, a list of the patents cited during the prosecution of such patent or a photostat copy of the entire official file of such patent may be obtained. Such list or copy will show, respectively, what patents are considered closest by the examiner or what rejecting arguments he used against such patent.

It should be understood that the only positive result from a preliminary search is obtained when a full anticipation is found. When no anticipation is found, and depending on the carefulness and extent of the search, it can only be said that probably no anticipation exists. Nevertheless, a search will minimize the risks as much as humanly possible and is essential before developing the invention or filing an application thereon.

Before the search is actually begun by the inventor, a record must be made of the mental concept or idea and the inventor's present thoughts as to the best mechanism for carrying out his idea. Such record or disclosure is necessary even when the inventor does his own preliminary searching and, of course, is unavoidable when another person is to understand the invention sufficiently to make a search for the inventor. The record now made is to establish the date of conception of the invention and should consist of:

(a) Clear drawings showing the structure to be used, in a general way. The drawings need not be detailed, mechanically perfect working drawings nor even to scale, but should have sufficient views to show both the structure and the manner in which it operates.

(b) A description referring to the parts in the drawing by reference numerals and stating both what the various parts are and what their function is in the whole device. The description should also state the problem to be solved, the disadvantages of prior structures which are now overcome and the advantages of the present invention over such prior structures. Brevity in description is no virtue, but completeness is. The drawing and description should be on a single sheet or permanently fastened together and should be in duplicate.

(c) Signature and dating of each sheet by the inventor and witnessing of at least the description signature by two or more persons, preferably not relatives or personally interested in the invention, competent to understand the invention and to whom the invention can be safely explained and who should date their signatures. A satisfactory form to use for witnessing is:

Understood and witnessed by—
John Jones, Dec. 3, 1941
Samuel Smith, Dec. 3, 1941.

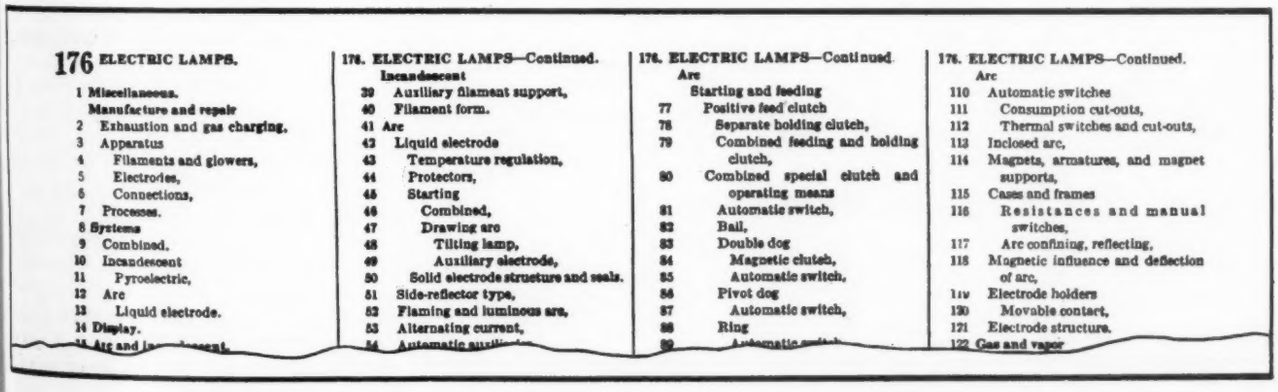
The above is the best of several means for making possible the future proof of the date of conception and of disclosure to others. Unless the witnesses understand the invention, they are competent only to prove the dates and not the subject matter disclosed.

A complete report should then be written on such preliminary investigation even though the investigation was made by the inventor himself. The report has the immediate effect of placing information regarding the invention in such form that a really complete application can be prepared. Attorney fees include the time of a man with both engineering and legal training and also his overhead expenses. A competent and ethical attorney's fees are necessarily high and any work done to present the invention to the attorney in its clearest form, with all supporting data, will be well repaid in fees saved.

The report of the preliminary investigation should therefore state the problem to be solved and the manner in which and the mechanism by which it is solved. A chronological history of the attack on the problem and the steps in its solution should be given with at least identification of and preferably copies of all data supporting such solution. The probable novelty of the invention should then be determined by stating the structural distinctions of the present invention over all prior patents, publications and similar manufactures found, to make sure that such distinctions appear in the claims. The advantages of the new structure and the new solution of the problem should be stated to give the attorney a basis for convincing the examiner that the invention is patentable. The report should list any dominating patents which might possibly be infringed by manufacture of the invention and should also list any complementary patents which might possibly be purchased to aid in securing control of the market for the invention.

The report writer, from his study of prior patents and publications, should form an opinion as to the trend along which similar devices are being developed and should determine whether the present invention represents a step forward along the trend or at an angle thereto or whether it is really a step backward. An invention made thirty years too soon or representing a too radical departure from current practice or having disadvantages not present in prior devices is seldom, if ever, marketable.

Finally, the report should state the field of search of both the classified patents and of other publications and should indicate that the searcher has no knowledge of other material to be searched, or should identify other known possible sources of pertinent material.



176 ELECTRIC LAMPS.

1 Miscellaneous.
Manufacture and repair
2 Exhaustion and gas charging.
3 Apparatus
4 Filaments and glowers,
5 Electrodes,
6 Connections,
7 Processes.
8 Systems
9 Combined.
10 Incandescent
11 Pyroelectric,
12 Arc
13 Liquid electrode.
14 Display.

176. ELECTRIC LAMPS—Continued.
Incandescent
39 Auxiliary filament support,
40 Filament form.
41 Arc
42 Liquid electrode
43 Temperature regulation,
44 Protectors,
45 Starting
46 Combined,
47 Drawing arc
48 Tilting lamp,
49 Auxiliary electrode,
50 Solid electrode structure and seals.
51 Side-reflector type,
52 Flaming and luminous arc,
53 Alternating current,

176. ELECTRIC LAMPS—Continued.
Arc
Starting and feeding
77 Positive feed clutch
78 Separate holding clutch,
79 Combined feeding and holding clutch,
80 Combined special clutch and operating means
81 Automatic switch,
82 Bail,
83 Double dog
84 Magnetic clutch,
85 Automatic switch,
86 Pivot dog
87 Automatic switch,
88 Ring

176. ELECTRIC LAMPS—Continued.
Arc
110 Automatic switches
111 Consumption cut-outs,
112 Thermal switches and cut-outs,
113 Inclosed arc,
114 Magnets, armatures, and magnet supports,
115 Cases and frames
116 Resistances and manual switches,
117 Arc confining, reflecting,
118 Magnetic influence and deflection of arc,
119 Electrode holders
120 Movable contact,
121 Electrode structure.
122 Gas and vapor

Fig. 7—The various classes of inventions are carefully divided and sub-divided into separate fields

ACCELERATION-SENSITIVE GOVERNORS

THE ADDITION of the principle of acceleration-response to existing centrifugal governor design will often do much to eliminate hunting and give closer control.

Operation of a centrifugal governor depends on the existence of an off-speed condition. Where the rectifying force may be subject to an inherent time delay, such as the inductance of a motor field winding, or where the speed-unbalancing forces may be large, centrifugal governing may be far from satisfactory for close regulation. Although centrifugal governors, carefully and elaborately designed, can be made to regulate speed to within 0.05 percent, in ordinary cases difficulty is likely to be experienced in eliminating hunting from such a governing system.

A pure acceleration-sensitive governor, or inertia governor, depends for its operation on the existence of a force tending to accelerate (or decelerate) the rotating mass, or rotor, to an off-speed condition. Obviously such a governor can respond fully when the rotor just begins to change speed. On the other hand, a centrifugal governor cannot operate until the off-speed condition is great enough to unbalance the centrifugal forces sufficiently to actuate the governor. Nevertheless an inertia governor alone is practically useless. It tends to maintain whatever speed at which it may accidentally find itself. It cannot be set for any speed. It has no absolute speed-sense and will resist any speed-changing force, even a corrective one initiated by itself.

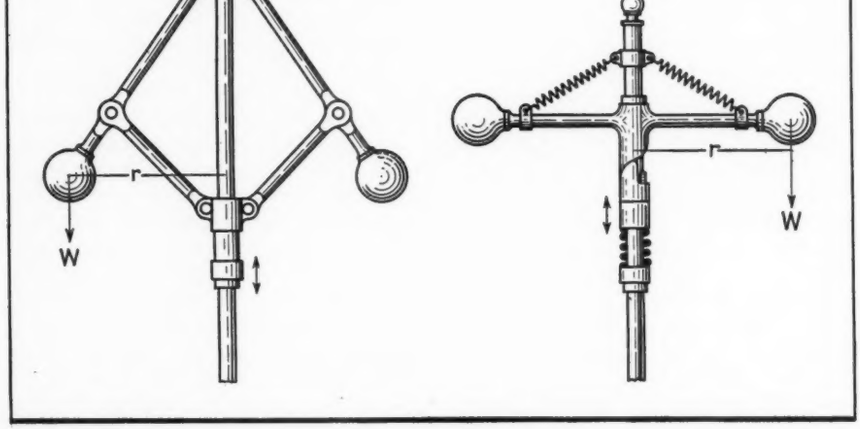


Fig. 1—In the standard fly-ball governor centrifugal force is used to give control. Fig. 2—Fly-ball construction can be converted into an inertia governor by changing the direction of freedom to produce the control

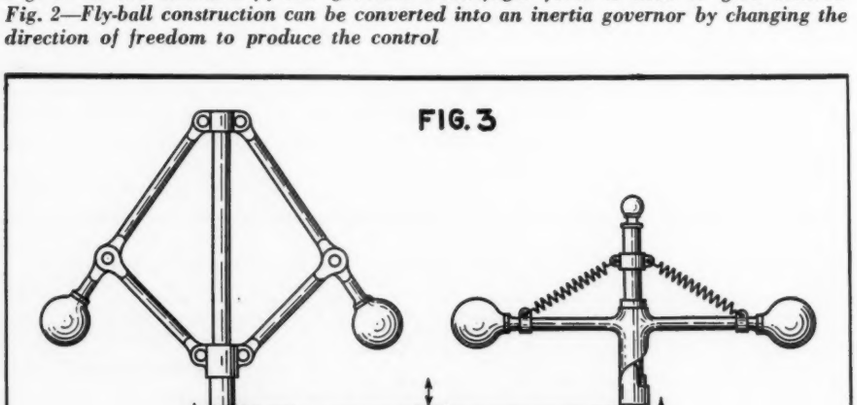


Fig. 3—By combining the two types a compound or acceleration-sensitive governor is produced.

However, the inertia governor, in combination with a centrifugal governor, results in an acceleration-sensitive governor which practically eliminates hunting and makes possible closer regulation. It is in such a combination that the inertia governor is always used. The combination may take two forms. It may be made of two units working together or of a single unit combining both features in a certain fixed ratio. The ratio or proportion of the two effects is of primary importance in the design of any governor incorporating both.

In the centrifugal governor shown in Fig. 1, various speeds, creating different centrifugal forces, result in new equilibrium positions for the balls and for the throttle control. The force on each ball may be expressed as

$$F = \frac{Wv^2}{gr} = \frac{Ww^2r}{g}$$

w = radians per sec. velocity
W = weight of ball in lb.
v = linear ball speed in ft. per sec.
r = radius of ball circle in ft.
g = acceleration of gravity in ft. per sec. per sec.

Hence, for each v a corresponding F exists which determines the extent of control.

In the pure inertia governor, shown in Fig. 2, the speed at which the governor happens to be running has no effect whatever on governor position as long as the speed remains constant. Any change in speed, that is, acceleration or deceleration, does affect immediately the governor position and affects it in proportion to the rate of change of speed. When the speed change ceases and, with it, the force of acceleration on the

ball, the governing action also ceases no matter what the final speed may be.

Here the force on each ball may be expressed as:

$$F = \frac{W}{g} \times \frac{dv}{dt} = \frac{W}{g} \times \frac{rdw}{dt}$$

where dv/dt = rate of change of linear ball speed in ft. per sec. per sec.
When v is constant, any fixed speed condition,

$$\frac{dv}{dt} = 0$$

$$F = \frac{W}{g} \times \frac{dv}{dt} = 0$$

Thus, at any speed, as long as that speed remains constant there will be no force exerted by the inertia governor. Such a governor will resist any change in speed but it cannot exert any influence tending to cause the machine to rotate at a specified speed.

If the devices of Figs. 1 and 2 are now assembled into a single governing unit as in Fig. 3, both affect the controlling action simultaneously. For very slow speed changes the centrifugal action will be primary; for sudden changes the inertia action will predominate and will give full corrective effort before the centrifugal unit begins to react.

It is important, however, that the two forces be correctly proportioned. Too little inertia effect will not correct rapid swings or prevent any over-correction by the centrifugal unit. Too much inertia effect will produce exaggerated corrections and hunting as a result of any sudden change.

To illustrate the operating principles of this system the following analysis may be helpful. In Fig. 4, curve *A* represents the deviation of the governed mass from governed speed, whether caused by load change or power input change. It represents the algebraic sum of the effects of a disturbing force and a corrective force on the speed. The abscissa is time, identical for all the curves of Fig. 4. Curve *B* represents the corrective effect of the centrifugal portion of the governor unit and can be seen to vary inversely with curve *A*. Curve *C* represents the corrective effect of the inertia, or acceleration sensitive, portion of the governor and varies with the slope of curve *A* which is a direct measure of the acceleration. Curve *D* represents the sum of curves *B* and *C*, that is, the total corrective effect. These corrective effects may be thought of in terms of forces or equivalent r.p.m.'s as long as the same terms are used for all of them. Only their relative proportions matter in this analysis; their absolute values are not needed.

As the speed of the rotating mass begins to increase, whatever the cause, curve *B* begins to follow negatively at a proportional rate. The ordinates of curve *C* immediately attain a negative value proportional to the negative slope of curve *A*. When the first effects of speed correction reduce the slope of curve *A*, which is still climbing, however, the negative ordinates at curve *C* start decreasing. As the rate of climb (acceleration) of curve *A* decreases, the inertia corrective effect decays correspondingly but the centrifugal effect continues to increase with amount of off-speed. The total corrective force is finally sufficiently large to counteract the disturbing forces entirely and then overcome it so that curve *A* reaches its peak where its direction is parallel to the time axis and therefore dv/dt is zero. At this point curve *C* goes through zero and then becomes positive. That is, from this point on the inertia corrective effect is aiding the original disturbing force and counteracting the centrifugal correcting force. But as shown in Fig. 4, curves *B* and *C* are so proportioned that their sum, curve *D*, still represents a considerable corrective force. As this force causes curve *A* to come down gradually but with increasing slope, the inertia corrective effect slowly increases in a positive direction, centrifugal corrective effect slowly decreases and the sum of the corrective forces, curve *D*, approaches zero. Zero corrective effect is reached at a point *N* where curve *A* is still some distance from governed speed reached at *Z*. From that point on, lagging effects including the inertia of all associated elements cause the speed to continue to decrease just enough to reach the governed speed.

The critical point in the design of any acceleration sensitive governor is to proportion it so that zero corrective effect, point *N*, shall always occur at

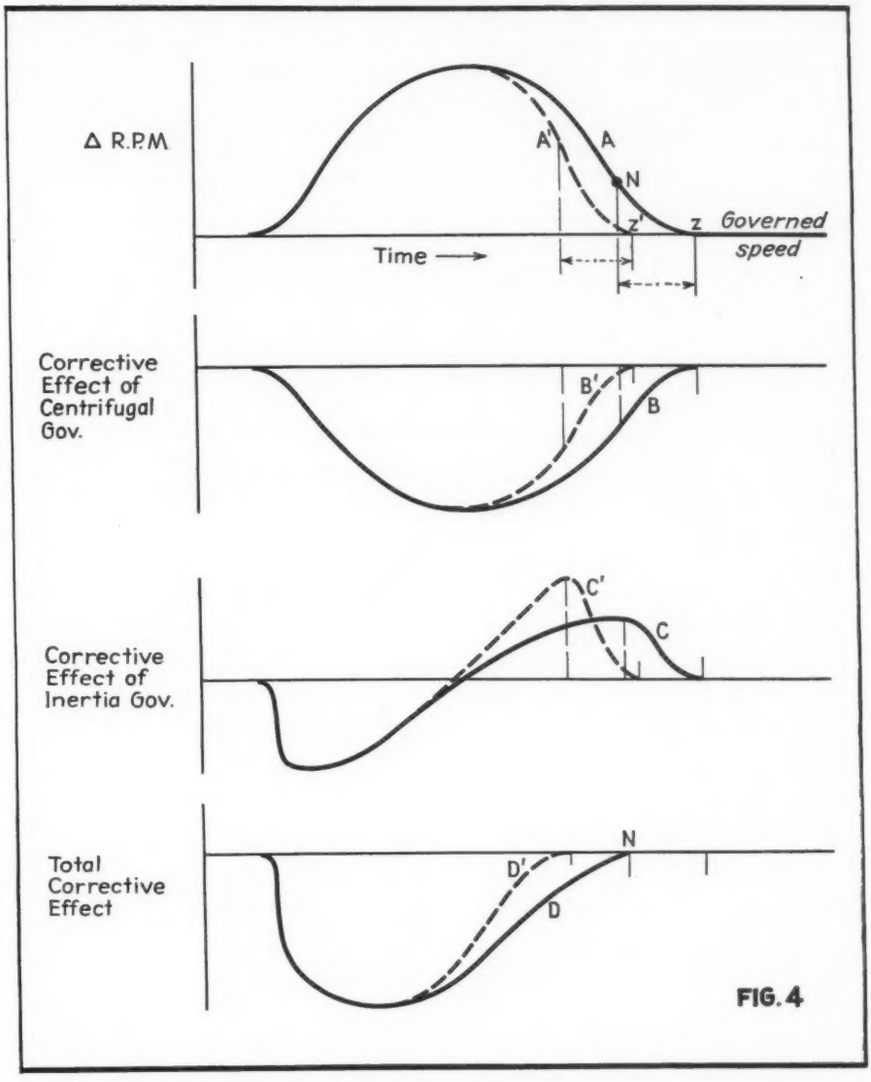


Fig. 4—Curves showing separate and combined corrective effects of centrifugal and inertia governors

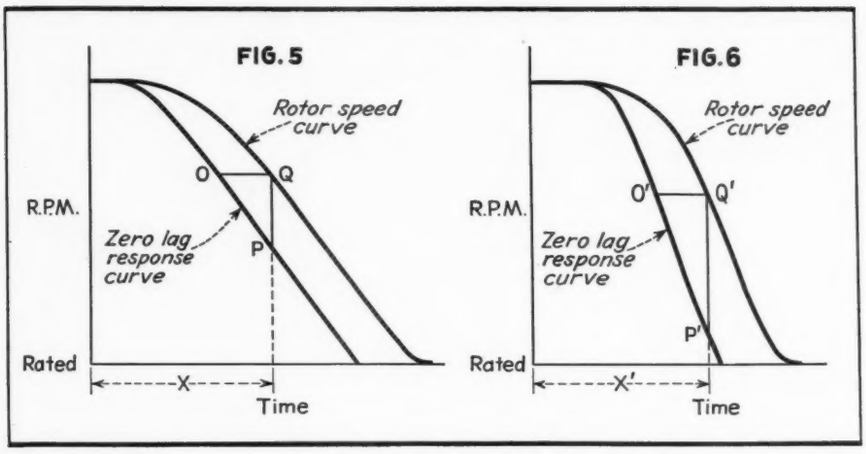


Fig. 5—Inertia of a rotor will prevent its changing speed directly with the corrective impulse. Fig. 6—Rate of rotor speed changes is increased by a high correction rate

a sufficient time interval before point Z as indicated in Fig. 4.

In Fig. 5, the lower curve represents the changing speed that the rotating mass would follow if there were no lag in its response to the governor, in other words, if it had zero time lag. The upper curve represents the actual path of changing speed taken by the rotating mass in following the corrective force exerted by the governor. When a stable correction condition has been reached, such as at time *X*, the vertical distance, *PQ*, between the two curves represents the rotor's lag in r.p.m. It is the residual speed correction that will still be made even if the governor at that moment ceases to exert further effort. The horizontal distance, *OQ*, represents the corresponding lag in time units and is generally referred to as the "characteristic time," *T*, of the system. This "characteristic time" is a measurement of the ratio of rotor inertia to available corrective torque per r.p.m. of off-speed, expressed generally in seconds, and is constant for each rotor-torque system.

Proper governing, then, requires that the corrective force of the governor reach zero at a point where the actual rotor speed (upper curve), which determines the corrective force, is still off governed speed by an amount equal to *PQ*, the r.p.m. lag. From this point the rotor's inertia should bring it directly into governed speed. As shown in Fig. 4, the proportioning of centrifugal and inertia corrective effects can be made to give just this type of control.

Disturbing forces may vary widely in magnitude and duration and the returning slope of curve *A* may also vary widely. Fig. 6 is Fig. 5 redrawn for a condition of much greater slope, that is, correction is taking place much more rapidly. It would be expected that the identical rotor would lag even further behind the now steeper slope of the lower curve, and, since the "characteristic time" of any one system is fixed, that is, *O'Q'* is identical with *OQ*, it is obvious that *P'Q'* must be larger than *PQ*. Such indeed is true and the r.p.m. lag will be greater for the conditions of Fig. 6 than for those of Fig. 5. Proper governing with therefore require that the corrective force, and with it the lower curve, be stopped when the upper curve is at a distance of *P'Q'* r.p.m. above the rated speed.

Again the inertia governor takes care of this requirement. Assume that increased steam pressure to a turbine or increased voltage to a motor produced increased corrective force for the same amount of governor response to off-speed. As in Fig. 4 curve *A'* would come down more rapidly than curve *A* and curve *B'* would follow in proportion. The positive section of curve *C*, however, would rise to a higher value and would thereby produce a zero sum of curves *B'* and *C'* (see curve *D'*) at a time when curve *A'* was at a higher point than it was in curve *A* of the same figure.

Still the zero sum point would occur before the *A'* curve reached zero, point *Z'*, by a length of time which will be enough to give the proper r.p.m. lag. Similarly were the slope of curve *A* decreased, curve *C* would not reach so high a value and the cutoff would occur at a lower point with regard to curve *A*. In each of these instances the zero point would be reached at a distance from the end of the cycle of whatever form of curve *A* that may occur which will give the necessary r.p.m. lag.

Thus all evidence goes to show that, in any one system, the proportioning of centrifugal and inertia effects depends on the "characteristic time," the inertia-torque ratio. For every system with its

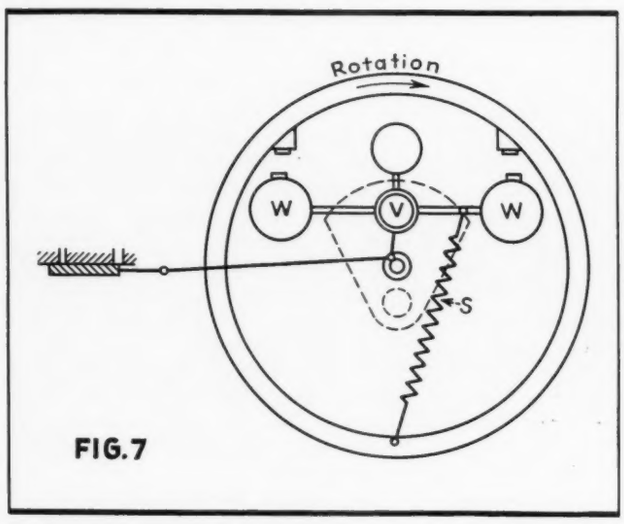


Fig. 7—"Inertia-Centrifugal" governor used by the Elliott Company to control their prime movers

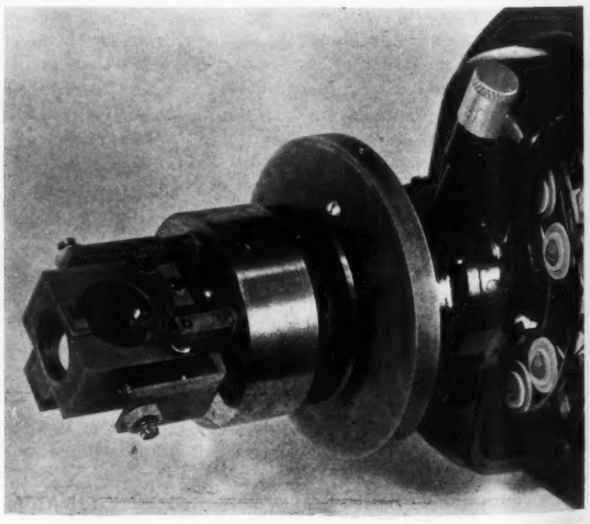


Fig. 8—Two-member acceleration-sensitive governor on submarine signaling motor-generator set

fixed T, there will be one combination of inertia and centrifugal forces to give the best results. No matter how the disturbing forces or corrective forces may vary, within design limits nor how the balance of forces may change during any corrective cycle, almost no over-swinging or hunting should result.

Naturally, an analysis such as that described is for some one type of control only. Different controls can produce various shapes of curves of corrective force, with constant slopes or varying slopes, but the same form of analysis should apply for all. Such factors as the inertia of governor units and operating mechanisms have been omitted but this does not impair the basis of the analysis.

While the analysis was for a mechanical form of governor, it is equally possible to use hydraulic or electric forms of acceleration-sensitive governing. Variations in pressure head or frequency or magnitude of an alternating current are some of the means used in such governors.

Although knowledge of the characteristics of inertia governors has been fairly widespread since the latter part of the nineteenth century, designers were able to do well enough with centrifugal governors. Early experiences with acceleration-sensitive governors were forgotten with the rise of centrifugal governor design. Some companies, however, produced satisfactory combinations of centrifugal and inertia governors and still continue to use them in steadily improved versions. One such company is the Elliott Company of Ridgway, Pa., whose Begtrup governor is in daily use on its steam powered prime movers.

As shown in Fig. 7, the Begtrup governor is mounted on the flywheel and combines centrifugal and inertia effects in a single unit. The spring S is fastened to one side of the balanced weight arm WW which pivots about point V some distance from the center of rotation of the flywheel. With the engine running at rated speed the spring holds the arm WW in the position shown which is at a slight angle to the position it would take without a spring. Any other speed, producing a different net centrifugal force on the arm, would result in a different equilibrium position and throttle setting which would act to return the flywheel to its original speed.

At the moment load is thrown on the engine the speed will tend to drop and inertia force will tend to swing the arm WW in a clockwise direction about V and thereby move the eccentric so as to give a later cut-off for the valve. The decreased centrifugal force at the lower speed will produce the same effect but an appreciable speed change must have taken place before this action becomes significant. The inertia effect begins immediately with the change in load. Obviously a decrease in load will have an opposite effect throughout.

The Westinghouse Electric & Manufacturing Company has given considerable attention to acceleration-sensitive governing in recent years and the work of their research department has resulted in the development of several noteworthy applications to electric motors. Fig. 8 shows a governor made up of separate centrifugal and inertia units acting together to control a submarine signaling motor generator set. The centrifugal unit is the pivoted member which contains a pair of weights tending to turn the pivoted member about the pivot axis under the effect of centrifugal force, and the inertia unit is the heavy flywheel from the side of which two contact carrying arms engage contacts on the side of the pivoted member. The combination of centrifugal and inertia effects regulates the pressure on the electrical contacts and varies contact resistance thereby.

In Fig. 9 is shown the same type of two unit governor used to control a five-horsepower motor generator set. Such simple, relatively sturdy units are capable of governing to within two percent and, in some sizes, to better than one percent. Such governors made up of two separate but interacting members can be used intact for many different applications merely by the adjustment of relative proportions of centrifugal and inertia effects. A single unit governor can be built for one application but the same governor is not likely to be usable for any other application.

The application of a combined type of governor for controlling a motor generator set is shown in Fig. 10. The small rotor pivoted at 45 deg. to the motor shaft axis is designed to provide both the inertia and centrifugal effects. Any change in the speed of rotation of the outer ring will produce an inertia torque on the small rotor which will have a component causing the rotor to turn in the ring. Any speed other than rated will cause centrifugal force to make a greater or lesser effort to line up the hole in the rotor with the outer ring which has a restraining spring. Both actions will affect the pressure of the contact points which are visible at the left rotor pivot.

Additional application of the acceleration-sensitive governor have arisen recently but most are shrouded under wartime secrecy orders. These examples do illustrate the possibilities of these rarely used governors.

Fig. 9—Commercial application of acceleration-sensitive governor to a 5 hp. motor-generator set

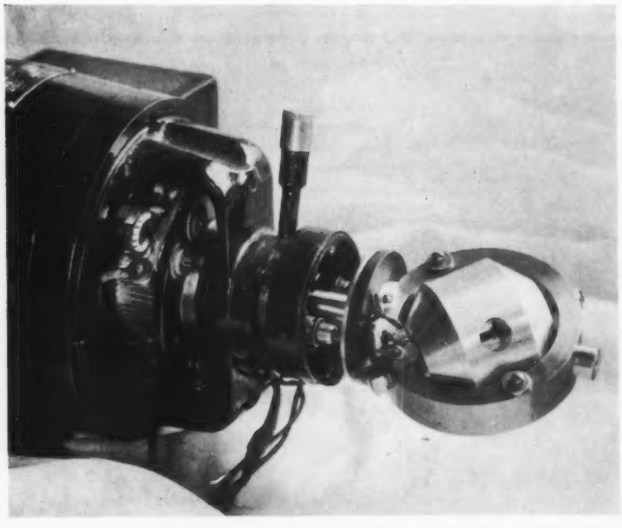


Fig. 10—Single-member acceleration-sensitive governor applied to a motor-generator set

WRENCH CLEARANCES

Required for Bolting-Up Pipe Flanges

ARTHUR H. KORN

DESIGNERS when making piping layouts and other bolted connections often have much difficulty in establishing the dimensions of areas which must be kept clear in order that joints can be assembled with facility. To conserve room, too much valuable space should not be allotted yet there must be sufficient to permit the use of wrenches for tightening flange bolts. If the designer depends upon guesswork to establish necessary clearances, the probability is that special tools will have to be made to reach into restricted places. This unnecessary cost on installation and repair jobs can be avoided.

Wrench clearances are largely governed by the minimum arc through which a wrench must swing when tightening or loosening a nut. This arc varies with the type of wrench. When a straight wrench is applied to a hexagon nut the wrench movement must cover an angle of 60 deg. before it can be returned to its starting position for a new bite on the nut and another 60 deg. turn. However, most open end wrenches are not straight but are like those shown in Fig. 1, the center line of the open end forms an angle with the center line of the wrench handle, usually 15 or 45 deg. When used on hexagon nuts such 15, 45 and even 75 deg. wrenches require only a movement of 30 deg., then if the wrench is turned over, that is 180 deg. about the axis of the wrench handle, a new bite can be taken on the nut in the original or starting position of the wrench.

Unfortunately, the advantages obtained through the use of this clever trick for reducing the sweep of a wrench is under most conditions almost wholly destroyed, at least as far as the 45 and 75 deg. wrenches are concerned, by another feature of wrench design. Open end wrenches have an offset, the center line of the wrench handle does not run through the center of the nut when applied. Thus the trick does not work because even though the open end

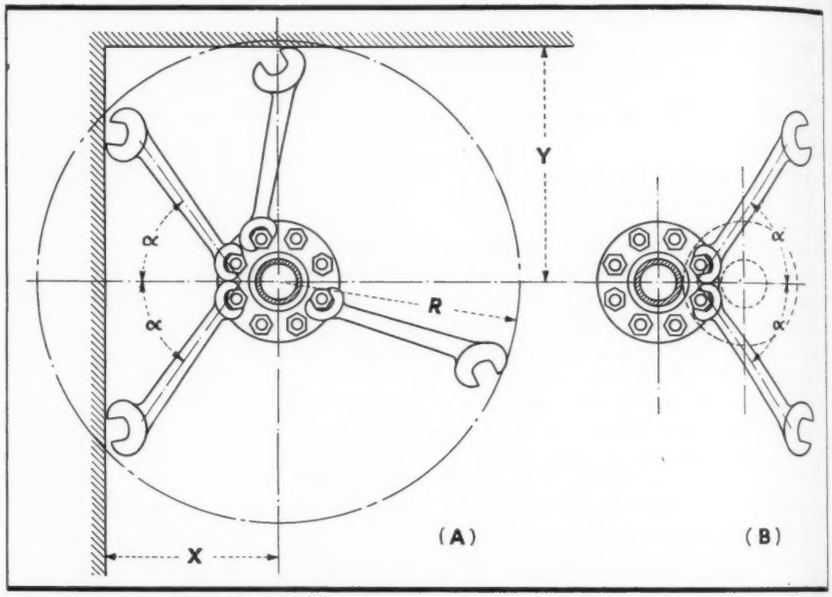


Fig. 2—(A) Minimum corner clearances required by wrenches to bolt-up a pipe flange. (B) Clearances required when pipe lines are close together

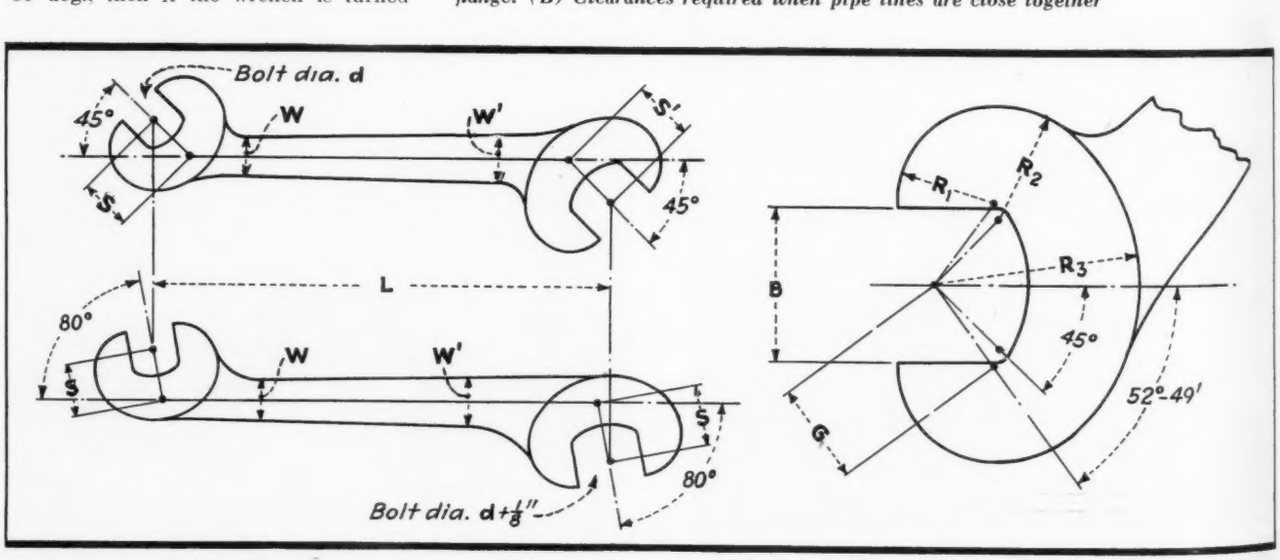


Fig. 1—Proportions of double open end offset wrenches used as a basis for calculating tables of clearances

of the wrench may move only through an angle of 30 deg., the wrench handle on account of the turning over will sweep an area much greater than that covered by a 30 deg. arc.

The offsets of wrenches have nevertheless some advantages. If the bolts are in a straight row the movement of a straight wrench may be limited by neighboring bolt nuts, however, wrenches can be made with sufficient offset so that the wrench handle will be parallel to the row of bolts, thus obtaining a better starting position in that the wrench handle would not project away from the row as much as would a wrench without offset.

When bolting up the movement of a wrench may be limited either because the wrench handle will strike an adjoining nut or by the fact that the jaws of the open end wrench will contact the hub of the flange. If a 45-deg. offset wrench is used both conditions will occur in more or less the same wrench position on nearly all flanges which have more than 4 bolts. Moreover, in this limiting position the wrench handle will be almost tangential to the flange. These facts make the 45-deg. offset wrench ideal for pipe work. In spite of the fact that the 45-deg. offset wrench has to swing through an angle of 60 deg., it requires less clearance space than that needed by the 15-deg. wrench which requires an angle of only 30 deg. for swing. The reason for this is that the 15-deg. wrench projects more or less radially from the flange.

In places where it is necessary, the clearance space required by a 45-deg. offset wrench can be effectively reduced by the additional use of an 80-deg. offset wrench. The author's attention was first directed to this unusual wrench through an article by W. H. Wilson, "Several Piping Tools I've Found Handy," (*Heating, Piping and Air Conditioning* V. 4, p. 808). Subsequent closer investigation has shown that with such a wrench when used alternately with a 45-deg. offset wrench, clearance spaces on pipe lines can be cut to the minimum obtainable with two wrenches, and on some flanges to the minimum possible under any circumstances.

Even after a selection of the most advantageous kind of wrenches has been made the designer may have considerable difficulty in establishing a table of dimensional clearances that will hold true for all makes because wrench dimensions are not standardized. In order to check the accuracy of any table of clearances that he may make for wrenches with offsets different from those used to calculate the tables included in this article, the designer should collect from various sources

Table I—Flanged Pipe Clearances

Required for Double Open End 45 Deg. Offset Wrench

Dimensions X, Y and R in in. α in Deg.

Nominal Pipe Size	Steel Flanges 150 lb. per sq. in. Cast Iron Flanges 125 lb. per sq.in.				Steel Flanges 300 lb. per sq.in. Cast Iron Flanges 250 lb. per sq. in.				Steel Flanges 400 lb. per sq. in.				Steel Flanges 600 lb. per sq.in.				Steel Flanges 900 lb. per sq.in.				Steel Flanges 1,500 lb. per sq.in.				Steel Flanges 2,500 lb. per sq.in.			
	X	Y	R	α	X	Y	R	α	X	Y	R	α	X	Y	R	α	X	Y	R	α	X	Y	R	α	X	Y	R	α
½	4.8	9.5	9.8	74									5.1	9.6	10.0	72									6.6	14.1	14.6	76
¾	4.9	9.6	10.0	75									6.3	11.9	12.4	72									7.0	14.2	14.7	74
1	5.3	9.7	10.2	73									6.5	11.0	12.5	71					8.2	16.3	16.9	73	8.1	16.5	17.2	74
1¼	5.5	9.9	10.4	72									6.7	12.1	12.7	71					8.7	16.6	17.3	72	9.4	18.8	19.6	74
1½	5.3	10.0	10.6	75									7.4	14.4	15.1	73					9.6	18.7	19.5	72	10.1	21.1	22.0	75
2	6.2	12.4	13.1	77	9.7	11.8	13.2	54					9.7	13.0	13.3	54									15.4	20.2	20.5	50
2½	6.7	12.7	13.5	82	11.7	14.8	15.7	53					11.6	15.6	15.8	53									15.6	22.5	23.0	59
3	6.5	12.9	13.7	77	12.6	15.8	16.1	47					12.0	15.9	16.2	51									18.1	25.3	25.8	56
3½	9.5	13.7	14.2	64	12.4	16.3	16.4	54					14.3	18.3	18.6	50												
4	9.8	13.9	14.5	61	12.3	16.5	16.7	55	14.4	18.6	18.8	51	14.0	18.9	19.2	56	17.1	20.9	23.8	55	19.0	25.6	26.1	53	21.1	30.1	30.8	58
5	12.8	16.8	17.1	54	13.3	17.2	17.4	53	14.8	19.3	19.5	52	15.6	21.9	22.3	59	18.9	23.3	26.8	57	22.7	30.7	31.2	53	25.2	35.3	36.1	57
6	13.6	17.3	17.6	51	14.6	17.6	18.1	50	16.3	19.7	20.1	48	18.4	22.2	22.8	47	20.3	21.7	25.5	48	23.9	29.1	29.7	45	28.0	40.3	41.2	56
8	14.4	18.3	18.7	53	17.3	20.8	21.4	50	19.2	23.0	23.5	47	21.2	25.4	26.1	46	21.9	28.2	31.2	48	28.7	34.6	35.4	45	34.3	41.6	42.5	45
10	18.7	19.3	22.0	41	21.5	21.5	24.6	40	23.8	23.8	26.7	38	26.0	26.0	29.9	39	28.5	28.5	32.7	39	33.9	40.5	41.3	44	42.7	51.8	53.0	45
12	19.3	20.5	23.4	49	24.3	24.3	28.0	41	26.5	26.5	30.1	39	28.2	28.2	31.0	34	31.0	31.0	34.0	34	40.1	40.1	45.2	37	47.2	57.3	58.7	46
14	21.5	23.4	26.4	51	26.4	26.4	29.2	38	28.6	28.6	31.3	34	30.8	30.8	33.8	33	33.3	33.3	36.6	33								
16	23.9	23.9	27.6	44	28.3	28.3	32.4	38	31.5	31.5	34.5	35	34.0	34.0	37.5	34	36.3	36.3	39.8	34								
18	27.1	27.1	30.5	40	30.8	30.8	33.6	35	33.5	33.5	35.7	30	37.2	37.2	40.6	33	41.4	41.4	45.4	33								
20	28.6	28.6	31.6	38	31.7	31.7	34.7	36	36.4	36.4	38.9	30	39.1	39.1	42.0	30	44.3	44.3	48.8	31								
24	32.8	32.8	36.0	37	37.7	37.7	41.4	36	42.7	42.7	45.5	31	45.6	45.6	48.5	30	55.0	55.0	59.2	33								

Table II—Flanged Pipe Clearances

Required for the Combined Use of Double Open End 45 Deg. and 80 Deg. Offset Wrenches

Dimensions X, Y and R in in. α in Deg.

Nominal Pipe Size	Steel Flanges 150 lb. per sq.in. Cast Iron Flanges 125 lb. per sq.in.				Steel Flanges 300 lb. per sq.in. Cast Iron Flanges 250 lb. per sq.in.				Steel Flanges 400 lb. per sq.in.				Steel Flanges 600 lb. per sq.in.				Steel Flanges 900 lb. per sq.in.				Steel Flanges 1,500 lb. per sq.in.				Steel Flanges 2,500 lb. per sq.in.			
	X	Y	R	α	X	Y	R	α	X	Y	R	α	X	Y	R	α	X	Y	R	α	X	Y	R	α	X	Y	R	α
½	2.1	9.8	9.8	109									2.2	9.9	10.0	107									3.0	14.3	14.6	111
¾	2.2	9.9	10.0	110									2.4	12.3	12.4	107									3.1	14.5	14.7	109
1¼	2.3	10.1	10.2	108									2.5	12.4	12.5	106					3.4	16.8	16.9	108	3.6	17.2	17.2	109
1¼	2.5	10.2	10.4	107									2.6	12.6	12.7	106					3.7	17.1	17.3	107	4.1	19.3	19.6	109
1½	2.6	10.3	10.6	110									2.8	14.8	15.1	108					4.0	19.3	19.5	107	4.5	21.5	22.0	110
2	3.2	12.7	13.1	112	5.1	12.2	13.2	89					5.1	12.2	13.3	89					7.8	16.8	18.2	84	8.2	19.0	20.5	85
2½	3.6	12.7	13.5	117	6.1	14.5	15.7	88					6.1	14.5	15.8	88					7.5	19.2	20.8	89	6.8	21.4	23.0	94
3	3.8	13.1	13.7	112	7.4	14.8	16.1	82					6.4	14.6	16.2	89	6.5	17.0	18.7	92	8.6	21.4	23.1	87	8.4	23.8	25.8	91
3½	4.7	12.6	14.2	97	6.8	14.8	16.4	89					8.0	16.9	18.6	85												
4	5.0	12.7	11.5	97	6.6	14.9	16.7	90	7.9	17.1	18.8	86	7.1	17.2	19.2	91	8.5	21.7	23.8	90	9.6	23.9	26.1	88	9.0	28.5	30.8	93
5	7.1	15.0	17.1	89	7.7	15.6	17.4	88	8.3	18.0	19.5	87	7.7	19.7	22.3	94	9.2	24.2	26.8	92	11.4	28.7	31.2	88	11.5	33.2	36.1	92
6	8.1	15.8	17.6	86	9.6	17.7	18.1	81	10.0	18.8	20.1	83	11.3	21.4	22.8	82	12.4	23.8	25.5	83	14.4	28.1	29.7	80	13.5	37.9	41.2	91
8	8.9	16.7	18.7	88	11.4	19.6	21.4	82	11.4	21.9	23.5	82	13.3	24.2	26.1	81	15.2	29.0	31.2	83	17.5	33.5	35.4	80	20.4	40.5	42.5	80
10	12.8	20.4	22.0	79	15.2	22.9	24.6	73	16.7	25.2	26.7	73	18.1	27.8	29.9	74	19.7	30.3	32.7	74	21.1	38.9	41.3	79	25.3	50.4	53.0	80
12	13.2	21.1	23.4	82	17.3	25.8	28.0	74	18.6	28.2	30.1	74	21.1	29.4	31.0	69	23.1	32.1	34.0	69	27.6	42.8	45.2	72	27.8	55.5	58.7	81
14	14.1	23.6	26.4	82	19.8	26.9	29.2	71	21.4	30.9	31.3	69	23.0	31.1	33.8	68	23.8	34.1	36.6	68								
16	18.0	21.5	27.6	73	21.9	29.8	32.4	71	23.5	32.1	34.5	70	25.5	35.2	37.5	69	26.8	37.0	39.8	69								
18	19.5	28.2	30.5	74	24.1	31.1	33.6	69	26.1	33.6	35.7	65	28.0	39.0	40.6	68	30.7	42.3	45.4	68								
20	22.0	28.9	31.6	70	25.1	32.0	34.7	70	28.4	36.7	38.9	65	30.5	39.4	42.0	65	32.8	45.3	48.8	69								
24	25.3	32.9	36.0	70	29.8	38.0	41.4	70	33.1	42.8	45.5	66	35.9	44.6	48.5	65	40.4	56.0	59.2	68								

wrench dimensions of what can be considered good practice and then provide additional clearances should the actual wrench length be greater than that used as the basis for his table. Such instances, however, should be rare.

As a basis for establishing the clearances as given in Tables I and II, because of their obvious advantage, the proportions of double open end wrenches were used. These proportions, as indicated on Fig. 1, were obtained from various sources.

d = bolt dia.

From Marks' Mechanical Engineers Handbook

Length of wrench $L = 15\frac{1}{4}\ d$

From Machinery's Handbook

Offset of wrench $S = 1\ 3/8\ d + 1/8$ in.

$S' = 1\ 3/8\ (d + 1/8$ in.$) + 1/8$ in.

Width of handle

$W = 1\frac{1}{4}\ d + 1/8$ in.

$W' = 1\frac{1}{4}\ (d + 1/8$ in.$) + 1/8$ in.

From PRODUCT ENGINEERING, Oct. 1940, p. 463

Radii of jaws

$R_1 = 1.0023d + 0.0835$ in.

$R_2 = 1.1544d + 0.0962$ in.

$R_3 = 2.0047d + 0.1617$ in.

$G = 0.9415d + 0.0785$ in.

From American Standards Association, B18.2—1933

Wrench openings B

Bolt nuts *American Standard Heavy*

Also in calculating the values given in Tables I and II, it was assumed that any given wrench size as measured by the bolt diameter on the flange for which the clearances are determined was paired with an opening at the opposite end for the next larger size of bolt, the increment being ⅛ in. Clearances necessary to bolt up the flange joints were calculated, as shown in Fig. 2 (A), for two sides of a rectangular boundary. The minimum clearance X from center of pipe to wall, ceiling, floor, or any inclined straight surface must be measured on a pipe center line that is straddled by the bolt holes. When this minimum clearance X is used the clearance at right angles to it will become Y, which is usually larger than X in the same plane. The circle described by the radius R represents the maximum area swept by the wrench when not impeded by any objects other than the flange itself. It is also important to remember that when two pipe lines have to be put together as close as possible that they should be placed so that there is no encroachment on the area which lies outside of that bounded by the outline of the wrench when in the limiting positions as designated in Fig. 2 (B) by the angle 2 α. This condition, of course, holds for each of the two pipe lines.

CHROMIUM and ALLOY STEELS

About one-quarter of the 1940 supply of chromium went into non-essential uses which can be eliminated without hardship in order to maintain the supply for essential uses in defense and industry.

POSSIBLE WAYS TO CONSERVE CHROMIUM

(1) Eliminate stainless steel trim for decoration and analogous non-engineering uses.
(2) Use of stainless-clad steel to replace solid stainless.
(3) Substitute other corrosion resistant materials for stainless.
(4) Replace chromium in cast iron by molybdenum or phosphorus plus titanium.
(5) Substitute carburized or surface hardened carbon or silicon-molybdenum steels for carburized chromium steels.
(6) Substitute silicon-molybdenum steels for chromium steels.

CHROMIUM USES OF CRITICAL IMPORTANCE WHICH TAKE NEGLIGIBLY SMALL PROPORTIONS

(1) High-speed steel with 4 percent chromium. No substitute known.
(2) Hot die steels, shear blades, wear-resistant steels. Not substitutable.
(3) Heat-resistant and corrosion-resistant tubing, etc., for oil industry, taking 4 to 9 percent chromium. No adequate substitute known.
(4) Heat-resistant castings, 12 to 25 percent chromium, for heat-treating furnaces, etc. No substitute known.
(5) Armor plate, 1 to 3 percent chromium in various grades. No presently known substitute.
(6) Low alloy, high yield strength structural steels. Certain types use small amount of chromium for atmospheric corrosion resistance. Because of reduction in amount of steel needed in designs that utilize higher strength steel, this use of chromium makes for conservation.

CHROMIUM PLATING

This use accounts for negligible tonnage. Average plate is only 0.0001 to 0.0002 in. thick. Although plating is apparently used chiefly for "glitter," it is also applied for rust-resistance or to protect against tarnish, wear and scratches, previously applied rust-resisting coatings that are relatively soft.

NON-FERROUS ALLOYS

Chromium in thermocouple wire, resistor wire for high temperature operation, and in Inconel, the last for aircraft exhaust manifolds, performs too important services to be disturbed. A tiny amount in special copper-base and aluminum-base alloys also serves useful purposes.

STAINLESS SANITARY AND CHEMICAL USES

Many food-processing operations carried out on an industrial scale use stainless to simplify sanitation. Enameled steel can often be substituted or stainless-clad steel may be applicable, or ceramic materials.

Many chemical processes are carried out best in stainless steel apparatus, generally fabricated by welding. Stainless steel liners for heavy steel vessels have been spot welded or spun in. Stainless-clad steel may present problems in welding joints but is usually feasible and ought to be used instead of solid stainless if design can possibly be engineered to permit.

Substitution by copper, silver, enameled steel, plastics, glass, stonewear, carbon, high silicon and cast iron may be applicable. Designers should examine all cases to see whether stainless cannot be spared.

ENGINEERING USES FOR STAINLESS

Austenitic stainless steels, such as the 18–8 type deserve use for their high strength and high endurance limit in various applications where their corrosion resistance is of no moment. For such uses there is no clearly defined substitute.

There are engineering uses where a stainless part is needed because reasonable strength and avoidance of rusting are both wanted. In such applications the copper-silicon alloys (silicon bronze) are often satisfactory, easy to fabricate, and obtainable from many sources. Where copper color is not desired, silicon bronzes can be copper-plated first, then given a flash of chromium plating.

USES IN CAST IRON

Chromium stabilizes the carbide in cast iron and is added in small amounts for this purpose to cast irons in which permanence of dimensions at elevated temperature is desired. There is no adequate substitute for this purpose.

Chromium increases tendency of cast iron to chill harden. When this tendency is counteracted by a larger addition of nickel or copper, the alloyed cast iron has increased strength. Such "balanced" irons are a common type of high strength cast iron. Similar effects are had by addition to molybdenum, but this is more expensive than the chromium-copper combination. An acceptable composition is 0.65 percent molybdenum, 0.10 percent vanadium. It has high strength and improved machinability over nickel-chromium cast iron. Thus, while it is partially substitutable, use of chromium in cast iron should not be wholly barred because the high strength irons may often be utilized in such fashion as to require considerably decreased weight of casting.

The only other chill-producing elements are an excess of sulphur over the manganese, which has only a mild effect and is seldom advantageous; vanadium which is perhaps even scarcer than chromium; molybdenum and manganese which have only a slight chilling effect; and tellurium, which is so potent that its effect is difficult to control. Tellurium might, however, ultimately serve as a partial replacement.

Development and use of a cast iron for cylinder liners in experimental en-

gines that contain about 0.75 phosphorus and 0.25 to 0.35 titanium is reported by A. L. Boegenold, General Motors Corporation. Wear resistance of this alloy without heat-treatment is equivalent to heat-treated nickel-chromium cast iron ordinarily used for cylinder liners.

SUBSTITUTES FOR HIGH-STRENGTH CHROME STEELS

Chromium carburizing steels, especially chromium molybdenum, have been used in place of nickel-molybdenum as well as for those uses in which they are preferred in their own right. As far as performance of finished parts go, possible substitutes for chromium carburizing steels for small parts are: (1) a forging grade of carbon steel with a thin gas carburized case; (2) a still higher carbon, plain carbon steel; (3) carbon-molybdenum steel, flame hardened or induction hardened on the surface.

The trend to 6100 (chrome-vanadium) series in the search for replacements for carburizing steels has put a drain on both chromium and vanadium. When this replacement is used, the chromium might well be reduced from the S.A.E. 6100 composition to avoid too high carbon in the case. Substitution by silicon-molybdenum or silicon-molybdenum with lower chromium than in the 6100 series is more attractive, not only for carburizing, but also for general engineering use.

Opinion of A. L. Boegehold is that "although molybdenum-manganese-silicon steels are not yet in production, they show promise of providing the answer to our problem of substitution because with 1.00 percent manganese and 1.00 percent silicon and 0.12 molybdenum, hardenability equivalent to that of S.A.E. 4615 steel is obtained and by increasing the molybdenum up to not over 0.30 percent hardenability equivalent to that of 3312 steel may be obtained.

"In almost the same category, from the standpoint of range of hardenability and freedom from strategic alloys, is X-9100 series steel which contains about 0.70 manganese and silicon, 0.15 molybdenum and 0.50 chromium. Either one of these two steels, or a combination of them, could be substituted for practically any engineering use. The reason they have not been adopted so far has been that their machinability is not as good."

Much unwarranted emphasis has been placed on core properties of carburizing on the assumption that the toughness of the carburized part increases with the toughness of the core. But any machine part with a brittle carburizing case behaves in relatively brittle fashion regardless of the properties of the core. Actual service more often than not has no real requirement for core toughness. Core hardness is needed to support the case.

Machinability and distortion are of greater actual import. Many applications of carburized steels could equally well use other compositions than those of the carburizing steels chosen. But the carburizing process, the heat-treatment and the machining and finishing by grinding would all require alteration to accommodate the different distortion and other characteristics of the new steel. Hence composition changes, once a steel has been selected and the shop tooled-up for it, are likely to cause trouble.

One use for chromium molybdenum steel for which no substitute should be urged at present is in tubing for aircraft fuselages, engine mounts, and other parts which are joined by welding.

Steels rather high in chromium have especially hard carbides which confer wear resistance. For some wear-resistant services, the use of chromium is well justified. The tonnage used for these purposes is relatively small.

While the carburizing, normalizing and welding steels and some wear-resistant steels that employ chromium may or may not be substitutable, those to be heat-treated by quenching and tempering are ordinarily substitutable, just as they have themselves been substituted for nickel steels.

Silicon spring steels, heat-treated in properly controlled atmospheres, will serve some purposes for which chromium-vanadium is employed.

SUBSTITUTION OF ALLOYING ELEMENTS IN STEEL

SILICON is available in profusion as silica. By use of man-hours and electric energy we can have as much ferrosilicon as we will.

MOLYBDENUM is plentiful, coming direct from the ores, and as a by-product from certain copper ores. It is a potent element, and in most of its uses in steel it can be employed as the oxide so that no smelting step is necessary. It is relatively expensive, about 85 cents per lb. contained molybdenum.

PHOSPHORUS is plentiful in the form of phosphate rock. With man-hours and electric energy provided, there is no limit to the amount of ferrophosphorus. Both silicon and phosphorus are cheap. Phosphorus is, within limits, a useful strengthening element for low carbon wrought steels.

COPPER is a useful alloying element in steel, used in limited amounts to avoid edge cracking on rolling.

NICKEL is austenitic stainless steel nickel is scarcely replaceable. Use of half or less of the customary amount of nickel in pearlitic steels along with an equal or somewhat greater amount of copper often produces results like those with all nickel and avoids difficulties that arise with copper alone. Addition of a suitable amount of nickel or nickel containing scrap would prevent this and widen the available scrap supply.

CHROMIUM. The role of chromium in stainless and heat-resisting alloys, and in high-speed tool steel is unique. A fraction of a percent is useful in many other steels, and, in some of them replaceable only with difficulty but in many others it is easily replaceable. Care needs to be taken to devote chromium only to its essential, non-substitutable uses.

MANGANESE is used in large amount. Only limited and doubtful application of substitute elements might be made in its main role, that of controlling sulphur and making steel rollable, whereas its strength-giving effects may often be satisfactorily obtained in other ways. Extreme caution is needed in employing manganese where other elements will serve.

VANADIUM cannot be substituted for in high-speed steel. In many other uses it can be aproximately substituted for, but not in all. Because, in other than tool steels, the usual addition is only 0.05 to 0.15 percent V, the cost is only been a sufficient deterrent to its inordinate use in the process of replacement of nickel steels.

ALUMINUM is used in small amounts, 0.05–0.10 percent, as a grain size control addition to steel. In this use it largely replaces vanadium, and as its cost is only 17 cents per lb., it is desirable to make this replacement. Provision of the small amount of aluminum necessary is vital, but requires only man-hours and electric energy.

TITANIUM plays a minor role much like that of aluminum. Contained titanium is, however, inherently somewhat more expensive than aluminum, so where either will serve, aluminum will be the choice. Titanium has some uses for which aluminum does not exactly serve.

FELT FOR INDUSTRIAL USES

Attention has been focused on wool felt during studies of materials best qualified for national defense. Physical properties applying more extensively than might be expected to both military and industrial requirements have been brought to light.

OFTEN ERRONEOUSLY CLASSED with textiles, felt's most highly developed uses are as an engineering material functioning in both construction and operation of machinery. However, many of its uses defy classification. For example its military uses include linings for soldiers' helmets, mounting pads for gun turrets in fighting planes, insulation in airplane fuselage and wings, and as a means of reducing vibration in army tanks. Equally definite but different reasons have led to selection of felt for other military uses—in canteens, gas masks, dust masks, mackinaw linings, insoles for shoes, parachute landing pads, jungle pack saddles, ammunition cases and so on.

Shortages in other materials, plus the frequent redesign of machines and products to satisfy changing requirements are broadening commercial applications of felt as a substitute for rubber, plastics, cork, wood, leather, cloth, paper and for other substances which are fast becoming unobtainable in adequate quantities.

FELT STRUCTURE

Felt is distinguished from other materials by the method of interlocking fibres by mechanical work, chemical action, moisture and heat to form a compact fabric.

The basic process consists in putting successive layers of fluffy carded wool "batts" in a mattress-like formation, which is steamed and ironed in a vibrating press and afterward steamed again, rolled upon itself, and beaten in a fulling mill until the mat has become shrunken, thickened and hardened to the required consistency. Processed in this manner wool becomes a three-dimensional fabric, having approximately the same tensile strength in all directions.

Similarly processed with other fibrous or filling material, felted wool retains the same characteristics and becomes the skeleton of a structure the properties of which depend upon the associated ingredients and the treatment to which they have been subjected.

Wool from sheep and lamb is the foundation for highest grades of felt although the hair of other animals possesses somewhat similar characteristics to a lesser degree.

Wool alone can be felted because of its kinky nature and interlacing tendencies where other fibres will not permanently interlock in the same way by themselves. In combination with other fibres it is the framework of the fabric. Impregnated with bonding agents it can be made to retain inert material, and to yield almost any physical properties that may be desired.

VIBRATION INSULATORS

In isolating vibration, loading should be kept below 50 lb. per sq.in. Efficiency as high as 80 percent elimination of vibration is obtainable with proper design. Small felt disks under each leg or corner of machine bed are recommended instead of felt sheet under whole machine. Felt area under machine with flat bed should be 1/20 of base area. Circular felt disks are reported superior to square pads. Felt thickness of 1 to 1½ in. is found best for most applications.

Machines having sidewise motion require anchoring felt to floor and machine. Such mountings must be designed to avoid transmission of vibration through anchoring devices.

Other characteristics that make felt suitable for this service are its almost elementary simplicity of application and its relative imperviousness to the effects of moisture, oil, corrosives or moderate changes of temperature.

PHYSICAL PROPERTIES

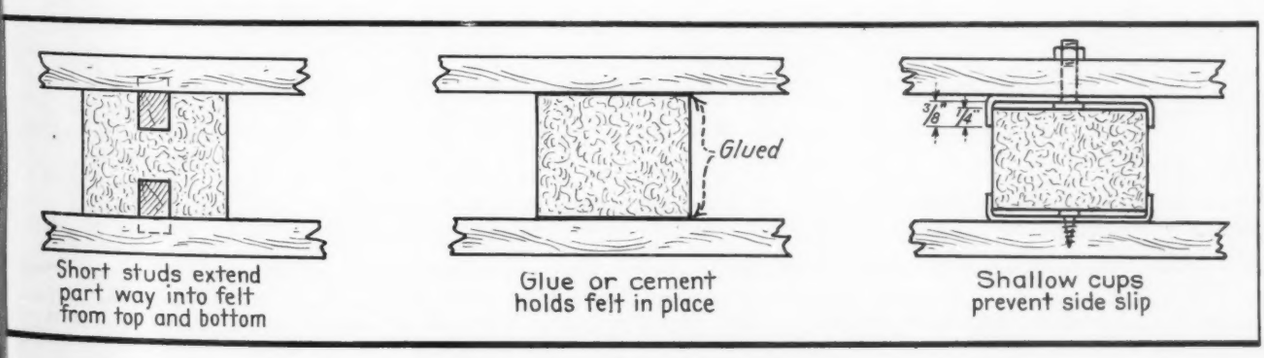
If felt be considered a flexible mechanism rather than a mere heterogeneous mass, its widely varying uses are more easily understood. For instance, wool fiber possesses great elasticity which is valuable in absorbing vibration and shock loads.

Loosely compacted wool, in a mat of random design but with highly uniform distribution of filament, serves as an excellent baffle to break up the pattern of gas vibrations. This accounts for its use as a sound deadener.

Tightly compacted wool develops progressively increasing resistance, becoming first a vibration dampener, and in the higher densities, an effective shock absorber. Hence, one of its most interesting uses is in mounting machinery.

POLISHING QUALITIES

The horn-like structure of the hair not only imparts stiffness, but enables felt to resist abrasion in contact with moving parts of machinery. Therefore, it is widely employed as a polishing material in itself, and as a carrier for abrasives used in polishing lenses,


Glued
3/8"
1/4"
Short studs extend part way into felt from top and bottom
Glue or cement holds felt in place
Shallow cups prevent side slip

Three designs of anchored felt mountings

plate glass, bright metals, jewelry and enamels.

MOISTURE ABSORPTION

Wool has a natural tendency to absorb moisture, which gives it multiple uses as a wicking material. Control of its absorption tendency permits the use of felt as both a retainer and a carrier of liquids, as in lubricating wicks or ink rollers and pads. Felt can also be designed to prevent the passage of moisture, liquids or vapors. Felt sealing washers in ball bearings keep oil in and dirt out, maintaining permanent lubrication and excluding destructive agents.

HEAT INSULATION

Felt is an excellent heat insulator and exhibits marked indifference to the effects of temperature from 250 deg. F. down to minus 100 deg. F. The fabric does not support combustion and can be flameproofed, as well as treated to render it water resistant, mildewproof and mothproof.

WORKABILITY

Felt is readily workable and will not ravel, regardless of how it is worked; hence it can be die-cut, skived and shaved. Finished surfaces are commonly produced by sanding. Certain felt parts are formed by turning in a lathe.

It can be worked to intricate patterns, taking and retaining close dimensions. Cut felts are often held to dimensional limits as firm as those required for metal parts, and the better qualities are now made with a guaranteed overall tolerance of 0.005 in. thickness. Also, it is produced in a much greater assortment of weights and thicknesses than any other fabric or material of a fibrous nature. Thickness may range from 0.025 in. to 3 in.; weight, from 3 oz. to 65 lb. per square yard.

DIVERSITY OF USES

General utility of felt is illustrated by its employment in air-conditioning units, and in business machines; also in conveyors, dust pads, embossing presses, gaskets and weather stripping. Its mechanical applications include looms, lawnmowers, pipe organs, radios, and tractors.

One of the highest types of wool felt is used in piano hammers. That required in surgery and in the preparation of foods and pharmaceuticals is necessarily of fine grades, fabricated under the most rigid quality controls.

Felt enters into approximately 65 items in automobile design, a number of them requiring several pieces.

Inclosed airplanes are insulated with felt while felt gaskets are used to protect control leads and instrument piping in planes from the devastating effects of metal fatigue.

Electric motors are lubricated for long runs without attention by means of felt plugs having one end immersed in an oil well, while the other bears against the spinning armature shaft. Cold line pipe insulation has been achieved in refrigeration units by means of suitable felt.

DESIGNED MATERIAL

The fact that wool felt has so many applications and is used to accomplish a multitude of ends is misleading. It tends to imply that it is a stereotyped product which, wholly by coincidence, can be used in many different ways. Actually it is a designed material, fabricated and finished to fit a definite set of requirements in every case.

TESTING

A standard method of testing wool felt was adopted by the American Society for Testing Materials in 1940 and has been published. It covers methods of test for dimensions, weight, breaking strength, splitting resistance, matter soluble in carbon tetrachloride and in water, wool determination, and microscopic examination.

Table I—Chemical and Physical Properties of Felt

S.A.E. Specifications	Trade Name*	Color	Fibre		Min Cotton Content Fibre Basis	S.A.E. Specification Max. Ash	Thickness Tolerance ±Percent	Weight of Felt, Lb. per Sq. Yd. (F-60 is specified at 4.50 and 6.00 lb. per sq. yd. respectively for ¾ and 1-in. thickness)				
								Thickness, In.				Weight Tolerance ± Percent
			Wool Percent	Cotton Percent				⅛	¼	⅜	½	
F-1	Back Check	White	100	..	95	0.75	10	2.00	4.00	6.00	8.00	5.0
F-2	Back Check	Any Color	100	..	95	1.00	10	2.00	4.00	6.00	8.00	5.0
F-3	Back Check	Gray	95–100	5	95	1.25	10	1.95	3.90	5.85	7.80	7.5
F-6	Extra Firm Pad	Gray	100	..	95	0.75	10	1.75	3.12	4.62	6.12	5.0
F-7	Extra Firm Pad	Gray	85–95	5–15	80	1.00	10	1.75	3.12	4.62	6.12	7.5
F-10	Firm Pad	White	100	..	95	0.75	10	1.50	2.25	3.25	4.25	5.0
F-11	Firm Pad	Gray	100	..	95	1.25	10	1.50	2.25	3.25	4.25	7.5
F-12	Firm Pad	Gray	90–95	5–10	85	1.25	10	1.50	2.25	3.25	4.25	7.5
F-13	Firm Pad	Gray	80–85	15–20	75	1.25	10	1.50	2.25	3.25	4.25	7.5
F-15	Firm Pad	Gray	60–65	35–40	55	1.50	10	1.50	2.25	3.25	4.25	7.5
F-26	Soft Pad	Gray	50–55	45–50	45	1.50	10	1.10	1.90	....	....	10.0
F-50	Shoe Upper	Any Color	100	..	95	0.75	10					
F-60	Packing Felt	Gray	50	50†	40	5.00	15	....	1.50	2.25	3.00	10.0

* Back-check, extra-firm pad, and firm pad felts recommended for washers, bushings, oiling wicks, door bumpers, chassis strips. Soft pad felt is intended for body parts, and seats and back decorative motifs. Shoe upper felt is intended for oil reservoir washers and other uses where accurate, thin, smooth high-grade felt is desired. Packing felt is intended for such applications as soft top padding and silencing parts in body construction. † Cotton or other wool substitute.

PLATE GLASS

Types of plate glass and processing operations which can be used to add utility or decorative value. The information given here has been abstracted from the booklet "Glass and its Adaptability to Modern Needs," distributed by the Pittsburgh Plate Glass Company.

POLISHED PLATE GLASS—All clear glass, faces nearly optical planes and almost exactly parallel, as defined by U. S. Federal Specifications DD-G-451.

Modulus of rupture (tensile) ultimate ..... 6,500 lb. per sq. in.
Modulus of elasticity (Young's modulus) ..... 10,000,000 lb. per sq. in.
Specific Gravity 2.520
Hardness (Moh's scale) ..... 5.5 — 6.5
Weight per sq. ft. per inch of thickness ..... 13.16 lb.
Light transmission (¼ in. thickness)
  Total visible white light 0.90
  Total radiant energy transmission (¼ in. thickness) 0.774
Softening point ..... 1350 deg. F.
Coefficient of linear expansion ..... (deg. C) 8.02×10^{-6}; (deg. F) 4.45×10^{-6}
Thermal conductivity at 120 deg. F. (K) 6.674 (B.t.u. per sq. ft. per hr. per. in. of thickness per deg. F.)
Thermal conductance (U) Single plate (Air to air) ..... 1.13 (B.t.u. per sq. ft. per hr. per deg. F.)
Specific heat (0-100 deg. C; 32 deg.—212 deg. F) 0.205
Thermal Endurance
  (Heat shock to rupture 2 in x 2 in. x 7/32 in. samples, heated to a higher temperature and instantly plunged into water at 70 deg. F.) ..... 100 deg. F.
Generally resistant to most acids and other chemicals
Solubility (boiling distilled water)
  Total Solids ..... 0.167 percent
  Total Alkali ..... 0.050 percent
Load carrying capacity. Regardless of superficial area, the greatest uniformly distributed load which any square light of glass, supported on all four sides, will support, is 21,000 lb. times the square of the thickness in inches. Because of many factors affecting strength of glass and the wide variation between minimum and maximum strength determinations, the glass manufacturer should be consulted when high strength requirements are involved.

TEMPERED PLATE GLASS—Herculite tempered plate glass, developed by the Pittsburgh Plate Glass Company, is tempered by rapid heating followed by instant cooling. When broken it disrupts into small granular fragments that have relatively smooth edges. All fabricating processes must be done prior to heat-treatment. Other features of this glass are its high strength and hardness and high thermal endurance.

Modulus of rupture ..... 29,500 lb. per sq. in.
Hardness (Moh's scale) 8
Thermal endurance ..... 400 deg. F.
Safe working temperature (max.) ..... 650 deg. F.

SEMI-TEMPERED PLATE—For some uses and in some cases it is necessary to furnish only partly tempered plates which have a strength more than double that of annealed glass plate and a fracture characteristic between that of Herculite and annealed plate.

WATER WHITE PLATE GLASS—Especially designed for exceptionally high transmission of all the portions of the visible spectrum. Used for show-case windows, mirrors, photographic and blueprint equipment and similar applications.

Properties approximately same as for polished plate glass except as noted below:
Softening point ..... 1,390 deg. F.
Total radiant energy transmission 0.845
Total visible white light transmission 0.915
Solubility (boiling distilled water)
  Total Solids ..... 0.320 percent
  Soluble Alkali ..... 0.070 percent
This glass has the highest visible and total energy transmission of any plate glass product available. It has an unusually high transmission in the ultra violet range, 0.01 at 0.302 microns; 0.13 at 0.313 microns; 0.64 at 0.334 microns in ¼ in. thickness.

COLORED POLISHED PLATE GLASS—Obtainable as heat absorbing plate glass (Solex), flesh tinted plate glass, and blue plate glass. Rooms glazed with this glass will run 10 to 15 deg. cooler than rooms glazed with ordinary glass.

Properties approximately same as for polished plate glass except as noted below:
Solex R in ¼ in. thickness and Solex S in ⅛ in. thickness
  Total visible white light 0.70–0.75
  Total solar energy 0.35–0.45
  Total solar infra-red 0.11–0.17
  Total solar ultra-violet 0.40–0.61
Softening point ..... 1,317 deg. F.
Coefficient of linear expansion ..... (deg. C.), 8.34×10^{-6}; (deg. F.), 4.63×10^{-6}
Thermal endurance ..... 125 deg. F.

(continued on next page)

X-RAY LEAD PLATE GLASS—Has a lead content of about 61 percent. Used in applications where it is desired to screen against X-rays. Made only in one thickness, 5.35 to 7.35 mm., which is equivalent to at least 1/8 in. sheet lead.

The index of refraction of X-Ray lead glass is very high, namely	1.7571
Coefficient of linear expansion	(deg. C.), 7.30 x 10^{-6}; (deg. F.), 4.05 x 10^{-6}
Softening point	1155 deg. F.
Lead Equivalent (at 100 K.V.), guaranteed min	0.30
Light transmission, 1/4 in. thick	
Total visible white light	0.85
Thermal conductivity at 120 deg. F. (K)	.4.64 (B.t.u. per sq. ft. per hr. per in. of thickness per deg. F.)
Modulus of rupture	5,000 lb. per sq. in.
Modulus of elasticity	8,000,000 lb. per sq. in.
Specific heat (0—100 deg. C.; 32 deg.—212 deg. F.)	0.093
Specific gravity	4.879
Hardness (Mohs' scale)	1.27
Solubility (boiling distilled water)	
Total solids	0.050
Alkali	0.005
Thermal endurance	100 deg. F.
Average weight (6.35 mm. average thickness	6.37 lb. per sq. ft.

OPERATIONS ON GLASS PLATES

GLASS PLATES may be treated in many ways to add to their utility and decorative value. Some of these are the following:

BENDING.—Any of the foregoing products can be bent at the factory in an infinite variety of cylindrical, spherical and combination bends. Specific inquiry should be made concerning special applications contemplated.

ACID ETCHING.—By the action of hydrofluoric acid or its compounds, glass surfaces can be given frosted appearance or a semi-polished appearance in various degrees. Pleasing softone effects are sometimes obtained by acid polishing after sandblasting.

BLASTING.—Sandblasting is accomplished by blowing an abrasive such as sand in a stream of compressed air against the glass. A design to be sand blasted is cut out of a "resist" which is sealed to the glass. The resist may consist of a water soluble, gelatinous resin, rubber, or heavy adhesive paper or other similar material which is easily removed when the work is finished. Shading is accomplished by the successive removal of different portions of the resist, the finest sand blasting being done last.

Various "tones" or degrees of polish removal are required for different effects in executing a design or for the entire surface.

So-called "Carved Glass" is generally produced by deep blasting. By the "Sandaire" process letters, figures, and the like are cut out of glass plates by blasting through the plate. Also large holes and irregular cutouts may be "cut" out of glass plates by the blasting operation.

MUD GRINDING AND HONING.—The surface is ground smooth with the finest grades of sand and emery. The honed surface is not quite as fine a grain as the mud ground. These surfaces are similar in appearance to "acid frosting."

CHIPPING.—This is perhaps the oldest form of glass decoration. It results from coating sandblasted glass with glue and then drying out rather quickly. The glue adheres strongly to the glass, and as it dries and contracts, pulls chips out of the surface of the glass. No two chipped plates are ever alike. Delicate fern-like traceries as well as deep chipped effects can be obtained, depending upon the thickness of the glue film and the rate of drying. Double process chipping is merely the result of the application of a second coat of glue to a chipped surface. The resultant pattern is much more dense and non-transparent than single process chipped glass.

EDGING.—By grinding and polishing glass plate edges, the appearance is improved and the sharp edges are removed for safety. Beveled, seamed, swiped, flat, half round and pencil are common forms for the finished edge in the ground or polished finish.

DRILLING OF HOLES.—This is accomplished in the case of small holes by the use of rotating hardened steel bits with a lubricant of turpentine or kerosene. Larger holes are usually produced with rotating tube drills with an abrasive and water. Blasting also may be the method used for making holes especially of larger sizes.

ENGRAVING.—Engraving is surface work customarily done with narrow face power driven grinding wheels, and then usually polished. Blasting and polishing is also a method used in the execution of what are sometimes intricate and beautiful designs.

"ITALIAN" PROCESSING.—This consists in the application of colored paints or lacquers to designs blasted or engraved into glass surfaces.

CERAMIC ENAMELING.—Plates with various colored and diffusing effects can be produced by fusing onto the surface of a glass plate a thin layer of glass of the required properties. Usually the finely powdered glass enamel is sprayed on to the plate surface uniformly in some cases, or through a stencil if a design is required. For decorations, the enamel is often applied through a silk screen stencil.

PHOTO ETCHING.—Intricate designs and photographs can be copied onto glass and permanently etched in the surface. These etched lines and half-tone dots may be made more visible by edge lighting, by filling the lines with colors, or by silvering.

HERCULITING.—This process involves heating the glass plates to a temperature of approximately 1150 deg. F. and then chilling suddenly in a blast of air. The resulting increase in strength is dependent in degree on factors such as thickness of plate, rate of cooling, and uniformity of heating and cooling.

DECORATING WITH WOOD.—Wood veneer can be cemented to plate glass to produce a plate of fine appearance which has most of the advantages of a safety glass. With considerably less reflectance than a glass plate and no chance for dirt to get under the glass, this product is recommended particularly for table and desk tops. Other uses would include modern framed mirrors, picture frames, serving trays, plaques, wall panels, decorative panels and furniture tops.

Imitation wood effects are obtained by cementing decalcomanias to the back of the glass plates. This product is quite satisfactory in effect and durability for many purposes.

PERBUNAN RUBBER

PERBUNAN, the oil-resistant member of the Buna rubber family, is a copolymer of butadiene and acrylonitrile, with a specific gravity of 0.97. While there are both chemical and structural differences between Perbunan and natural rubber, Perbunan is more like rubber with respect to its processing than is any of the other synthetic rubbers commercially available. It is vulcanized by sulphur with accelerators used for rubber and by any of the methods employed on rubber. Over-vulcanization is not a problem. Also carbon reenforces Perbunan but to a much greater extent than rubber. Its resistance to petroleum and other oils at all temperatures make it suitable for hose, belting, cable sheathing, packings, seals, diaphragms, printing rolls and blankets, proofed goods and a wide variety of molded articles.

SOLVENT RESISTANCE

Perbunan is resistant to deterioration by aliphatic hydrocarbons but aromatic hydrocarbons, such as benzol, have a much greater tendency to swell Perbunan. Aromatic hydrocarbons, acetates, ketones and chlorinated hydrocarbons are good solvents for uncured Perbunan and also have a deleterious effect on cured compounds. The last four liquids in Table 1 are representatives of these four classes of chemical compounds.

HEAT RESISTANCE

Perbunan may be compounded for excellent heat aging and low compression set at elevated temperatures. Best heat aging compounds are loaded with semi-reenforcing and soft carbon blacks and are cured with accelerators which act as vulcanizing agents without added sulphur. These stocks also give low compression set at elevated temperature.

AGING

High age resistance is characteristic of Perbunan. In order to show enough deterioration to distinguish between different compounds the conditions of accelerated aging test must be severe. Where highest heat or age resistance is required, some advantages are obtained by adding antioxidant.

RESISTANCE TO LIGHT

Natural weathering tests indicate that Perbunan compounds containing 2 to 3 parts of commercial protective waxes are satisfactory after 18 months' exposure in accordance with

Table I—Swelling of Perbunan in Various Solvents

Liquid	Percent Swell 16 Days, Room Temperature		
	Perbunan 100	80 Perbunan 20 Rubber	Rubber 100
*85 percent Varsol No. 1 — 15 percent. benzol	37.5	54	194
SAE 20W Lubricating oil (Essolube)	6.0	7.5	54.5
Cyclohexane	30	67.6	203
Distilled water	2.3	2.1	1.0
Cottonseed oil	5	6.3	70
Turpentine	36.7	61.5	252
Methyl alcohol	12	8.6	3.1
Benzene	220	225	245
Amyl acetate	137	134	129
Acetone	142	102	14.9
Ethylene dichloride	317	256	146

Compounds:
Perbunan 100: Zinc oxide 5, Gastex 54, stearic acid 1, altax 1, sulphur 1.5.
Perbunan 80 — Rubber 20: Same as above.
Rubber 100: Equivalent volume leading to Perbunan compound; sulphur 2.75.
Compounds contain no softeners.

* Swelling produced by Varsol No. 1 and 15 percent benzol is greater than that produced by most petroleum products.

Perbunan compounds are resistant to animal and vegetable oils and may be used for linings, seals, or hose that contact them.

Tensile strength degradation and volume increase of Perbunan immersed in various vegetable and animal oils are shown in Table II. The following stock was used for this test:

Perbunan	100
Zinc Oxide	5
Stearic Acid	1.5
Dispersing Oil No. 10	10
P-33	100
D.P.G.	0.4
Santocure	0.4

Cured 45 min. at 287 deg. F.

Table II—Effect of Animal and Vegetable Oils at Room Temperature

	After One Week			After Three Weeks			After 3 Months
	Tensile lb. per sq. in.	Percent tensile retained	Elongation percent	Tensile lb. per sq. in.	Percent tensile retained	Elongation percent	Volume increase, percent
Control	2120	....	520	....	....	....	....
Cotton Seed Oil	2000	94	400	1960	92	425	—0.9
Linseed Oil	1790	84	470	2030	95	470	16
Olive Oil	1930	91	480	1940	91	500	2.9
Rape Seed Oil	2390	107	500	1910	90	500	0.4
Soya Bean Oil	1850	87	370	1530	72	350	0
Oleic Acid	2120	100	490	1900	89	420	35.3
Lard Oil	1990	94	450	2020	95	450	0.7

Tensiles calculated on basis of original unswollen gages.

A.S.T.M. Designation D518-38T, Method B. Compounds unprotected with "blooming" waxes check rapidly in direct sunlight. Such waxes are Sunproof and Heliozone.

Light colored pigments generally are less effective than the various blacks for resistance to light. Undercuring favors good resistance to the action of light. For best light resisting compounds, stocks should be cured to optimum or slightly under optimum cure as judged by tensile data.

ADHESION

Perbunan compounds may be secured to steel by means of chlorinated rubber cements, 125 C.P.S., obtained from Hercules Powder Company, or TyPly S cement, obtained from R. T. Vanderbilt Company. The metal should be roughened and be free of rust and grease.

Satisfactory chlorinated rubber (125 C.P.S.) cements can be made with 1 lb. chlorinated rubber per gallon toluene. To this is added 0.06 lb. dibutyl phthalate per gallon of toluene to act as a plasticizer for the chlorinated rubber. Two to four coats of this cement are used to coat the metal. Each coat is permitted to dry before the next coat is applied. With TyPly S a very thin cement coat is used.

Technique used with these cements is similar to established methods with natural rubber and other synthetics. Adhesion is satisfactory to plain carbon and alloy steels.

COMPRESSION SET

Compression set can be improved or controlled by varying sulphur content, time of cure, and selection of softeners. Excellent compression set at 250 deg. F. can be obtained by certain curing methods.

PERBUNAN-RUBBER MIXTURES

Mixtures of rubber up to 25 percent with Perbunan are important in improving processing of compounds. At optimum cure all compounds have similar tensiles and elongations over the whole range of mixtures. The 100 percent rubber stock is slightly softer and lower in modulus than mixtures or 100 percent Perbunan. Perbunan and rubber are compatible in all proportions.

Tensile, elongation, and hardness values after immersion for four days in Varsol-benzol at 140 deg. F. indicate that addition of up to about 50 percent rubber has little effect on oil resistance as measured by changes in these properties over the short period of test. However, oil resistance, as measured by swelling is very sensitive to presence of rubber. The accompanying chart shows swelling in Varsol-benzol is nearly a straight line function of the percent of rubber present.

Substitution of reclaimed rubber for part of Perbunan in a compound facilitates processing, improves tack and reduces cost. Addition of reclaimed rubber involves some sacrifice of oil resistance as with natural rubber and tensile strength is lowered.

ELECTRICAL PROPERTIES

Perbunan may be compounded to be electrically conducting by use of special types of carbon black. Specific resistivities of such stocks are contained in the following table.

Perbunan	100	100	100
Zinc oxide	5	5	5
Sulphur	1.5	1.5	1.5
Stearic acid	1	1	1
Altax	1	1	1
Gastex	100		
Acetylene Black (Shawinigan Products Co.)		115	
Stat-ex (Binney & Smith)			100
Cured 45 min. at 287 deg. F.			
Specific Resistivity, ohm-cms	222,000	106	2,200

To minimize variables no softener was added. In practical compounding it is necessary to consider the influence of softener.

POLYVINYL CHLORIDE IN PERBUNAN

Feasibility of utilizing mixtures of polyvinyl chloride, often classed as a synthetic rubber, with Perbunan is shown by tabulated properties of the following formula.

Perbunan	100 volumes
Polyvinyl chloride	100
Tricresylphosphate	80
Zinc oxide	5
Stearic acid	1
Altax	1
Sulphur	1.5
Channel black	50

Cure Conditions	15′/287°F.	30′/287°F.	60′/287°F.	120′/287°F.
Tensile, lb. per sq. in.	800	1510	1830	2050
Elongation, percent	350	480	450	430
Modulus, at 200 percent, lb. per sq. in.	610	750	880	1030
Hardness	67	68	70	71

Unplasticized polyvinyl chloride cannot be mill mixed with Perbunan, nor can too highly plasticized polyvinyl chloride be readily incorporated. The two phases must be of approximately equal plasticity for ready mixture. Addition of polyvinyl chloride to Perbunan improves flame resistance.

SOFTENERS

Softeners are used with Perbunan to a greater extent than with natural rubber to aid processing and also to impart specific properties to the vulcanizate. Standard Oil Company of New Jersey has classified 35 softening compounds for use of manufacturers in producing desired hardness modulus, resilience, freeze resistance, good heat aging, low set, insolubility in gasoline, high tensile, elongation, and hardness, and good processing qualities.

EFFECT OF PIGMENTS

Greatest re-enforcing effect and most severe retardation of four blacks investigated was channel black. Two thermatomic blacks have approximately similar physical properties and retard considerably less than channel black. Both have lower tensile strength, elastic modulus and hardness but higher elongation than do corresponding loadings of channel or semi-reenforcing blacks. Nearly all pigments so far investigated show retarding effects. Tests so far show most retarding produced by zinc oxide, clay and channel gas black.

[ACKNOWLEDGMENT. This data was taken from a new booklet prepared by Stanco Distributors, Inc., subsidiary of Standard Oil Company of New Jersey, producer of Perbunan.]

CORK FOR INSULATION

The largest use of cork is for thermal insulation, particularly for low temperatures, both in the form of corkboard and cork pipe covering. Various materials are available as substitutes in low-temperature service. Characteristics of these materials are compared here briefly.

WATER-VAPOR DIFFUSIVITY. The most serious obstacle to permanent efficiency of low-temperature insulation is penetration of water vapor. The thermal conductivity of any insulating material increases with increase in moisture content. Moisture is also likely to produce bacterial growth and subsequent decay in organic insulation. Some insulation may be disrupted at low temperature if condensed moisture turns to frost or ice.

VAPOR SEALS. Common practice is to vapor seal all low-temperature insulations on the warm or high pressure side and in many instances all sides. In spite of all practical precautions the vapor seal is often broken to some degree. If a perfect vapor seal were possible, almost any type of insulation having a low thermal conductivity coefficient and low coefficient of expansion could be used for low-temperature insulation. Excellent vapor stops in the form of asphalt saturated and coated papers are now available although the problems of application are still serious.

SEALED CASES. In factory-assembled mechanical refrigerators, cabinets, truck bodies, etc., it is possible to use a tightly sealed outer shell which can be insulated with low-conductivity material regardless of the water-vapor absorption characteristics of the insulation itself. The resistance of both the insulation and its vapor seal to the penetration of water vapor must be considered. In any case preference should be given to materials having a high water vapor resistance.

THERMAL CONDUCTIVITY. The conductivity constant K for corkboard and other materials is given in the accompanying table.

COMPRESSABILITY. Tests have shown that corkboard insulation has an average compression of 7 to 10 percent under a sustained load of 10 lb. per sq. in. or 1,440 lb. per sq. ft. for approximately 200 hr. When the load is removed the greater part of the original thickness of the cork is covered. The rate of heat flow through insulation increases in almost direct proportion to the decrease in thickness.

DENSITY AND SPECIFIC HEAT. Density is of importance where the insulating material is used in rolling stock, on ships and other applications where weight must be minimized. Specific heat is important where insulated containers are used for transporting perishable goods and in similar services where containers must be recharged with refrigerant periodically. The energy required to lower the temperature of a square foot of a given thickness of insulation from surrounding air temperature to the average low temperature is directly proportional to the mean temperature drop and to the density and specific heat of the material.

OTHER LOW-TEMPERATURE INSULANTS

"ROCK CORK," a widely used material at present, is made of mineral wool, paper pulp and asphalt. It is used both in sheets and for pipe insulation. It compresses 0.02 in. per in. thickness under load of 500 lb. per sq. in. Its temperature coefficient of linear expansion is 0.0000045 per deg. F.

HAIR FELT, which is made of chemically treated animal hair, is usually covered with a film of asphalt in the board form. In pipe covering each layer is protected with waterproofed felt. It is a non-structural material. Much cattle hair felt is used.

WOOL FELT is employed in much the same manner as hair felt. It is used to keep cold pipes from sweating and to prevent freezing of water lines.

FIBRE BOARD, made of wood fibre, cane fibre, etc., is usually vapor-proofed on the job in addition to vapor-proofing at the factory. It compresses 4½ to 11 percent under a load of 1,440 lb. per sq. ft. and has many uses.

REFLECTIVE INSULATION is polished aluminum foil, sometimes mounted on paper, and having variable physical properties. It is exceptionally light in weight.

GLASS AND MINERAL WOOL should be used within inclosed vapor-proofed walls. When used for pipe covering, they should be thoroughly vapor-proofed. They are non-structural materials.

REDWOOD BARK is the shredded bark and outer fibres of the redwood tree. It is non-structural and should be used only as fill within inclosed vapor-proofed walls.

CELLULAR GLASS has a high vapor resistance but is still an experimental material. It is bloated glass with a high percentage of closed pores and no capillarity.

"UNICEL," an expanded cork and vegetable fibre, emulsion treated, has not been produced commercially. It can be made also with palmetto wood instead of cork. Like corkboard, it has a low capillarity.

Properties of Cork and Other Low-Temperature Insulation

(K is expressed in B.t.u. per sq. ft. per deg. F. per hr. per in. at 65 deg. F., mean temperature)

Material or Form	Density lb. per cu.ft.	Conductivity K	Sp. Heat	Fire Hazard
Corkboard	7½ to 8	0.28	0.44	Slow burning
"Rock Cork"	14¾ to 17	0.30 to 0.32	0.27	" "
Hair Felt	8 to 21	0.31 to 0.33	0.32	" "
Wool Felt	17 to 27	0.27 to 0.29	....	" "
Fibre Board	14.5 to 17	0.33 to 0.36	0.32	" "
Reflective Insulation	Very light	low	....	Fireproof, except when mounted on paper
Glass & Mineral Wool	1.5 to 7	0.25 to 0.28	0.20	Fireproof
Redwood Bark (Packed)	2.5 to 6.5	0.23 to 0.30	....	Combustible
Cellular Glass	9.7 to 11.4	0.48	0.16	Fireproof
Sponge Rubber	4.5 to 5.7	0.21 to 0.25	0.30	Combustible
"Unicel"	5.5 to 7	0.27 to 0.29	....	Slow burning

COMMON HIGH BRASS

R. A. Wilkins and E. S. Bunn
Revere Copper and Brass Incorporated

The characteristics of common high brass, an alloy of copper and zinc, were discussed in Product Engineering for February along with charts for spinning and deep drawing brass, which are distinguished by slightly higher than average copper content for this series. Copper content ranges from 64 to 67.5 percent for the common high brass series as a whole although the term is often used in referring only to those brasses containing the lower amounts of copper.

Essential mechanical properties of common high brass strip containing 66.30 percent copper, and 0.03 percent iron and 0.02 percent lead, are given in Fig. 1 and Figs. 4 to 7 inclusive. The influence of five different ready-to-finish grain sizes on four properties of brass strip after annealing and work hardening are shown in these charts.

The mechanical properties of cold worked and annealed common high brass rod are given in Figs. 2 and 3 and Figs. 8 to 11 inclusive.

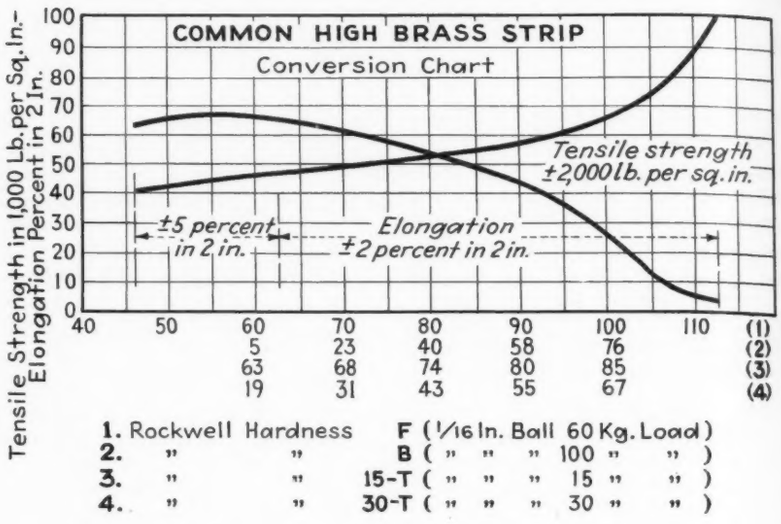

COMMON HIGH BRASS STRIP
Conversion Chart
Tensile Strength in 1,000 Lb. per Sq. In.–Elongation Percent in 2 In.
Tensile strength ±2,000 lb. per sq. in.
±5 percent in 2 in.
Elongation ±2 percent in 2 in.
100 90 80 70 60 50 40 30 20 10 0
40 50 60 70 80 90 100 110
(1) 5 23 40 58 76
(2) 63 68 74 80 85
(3) 19 31 43 55 67
(4)
1. Rockwell Hardness F (1/16 In. Ball 60 Kg. Load)
2. " " B (" " " 100 " ")
3. " " 15-T (" " " 15 " ")
4. " " 30-T (" " " 30 " ")

Fig. 1—This chart can be employed to determine the approximate tensile strength and percentage elongation of common high brass strip when only Rockwell hardness is known. Accuracy is within the given limits for all thicknesses between 0.020 and 0.080 in.

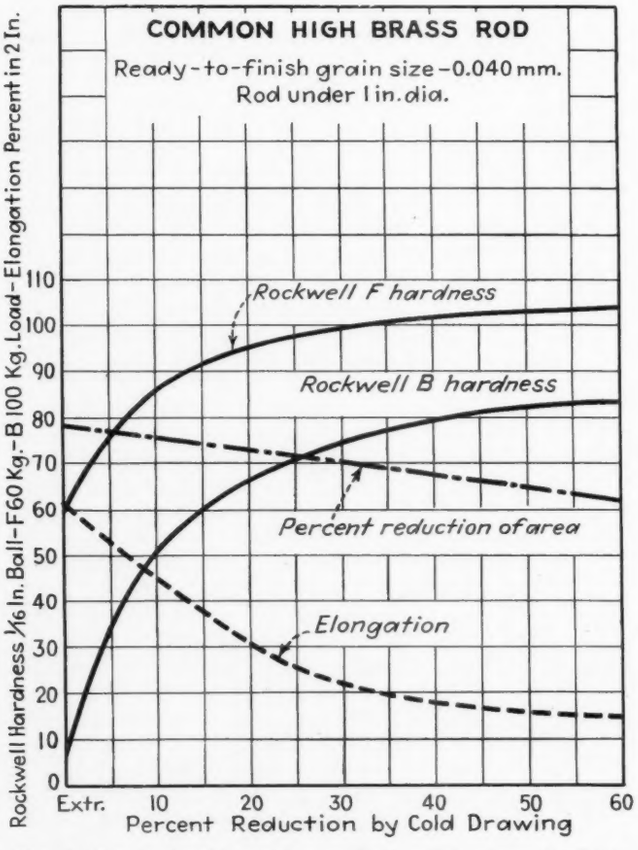

COMMON HIGH BRASS ROD
Ready-to-finish grain size–0.040 mm.
Rod under 1 in. dia.
Rockwell Hardness 1/16 In. Ball–F 60 Kg.–B 100 Kg. Load–Elongation Percent in 2 In.
Rockwell F hardness
Rockwell B hardness
Percent reduction of area
Elongation
110 100 90 80 70 60 50 40 30 20 10 0
Extr. 10 20 30 40 50 60
Percent Reduction by Cold Drawing

Fig. 2—Effect of cold working on Rockwell hardness F and B, reduction of area and elongation

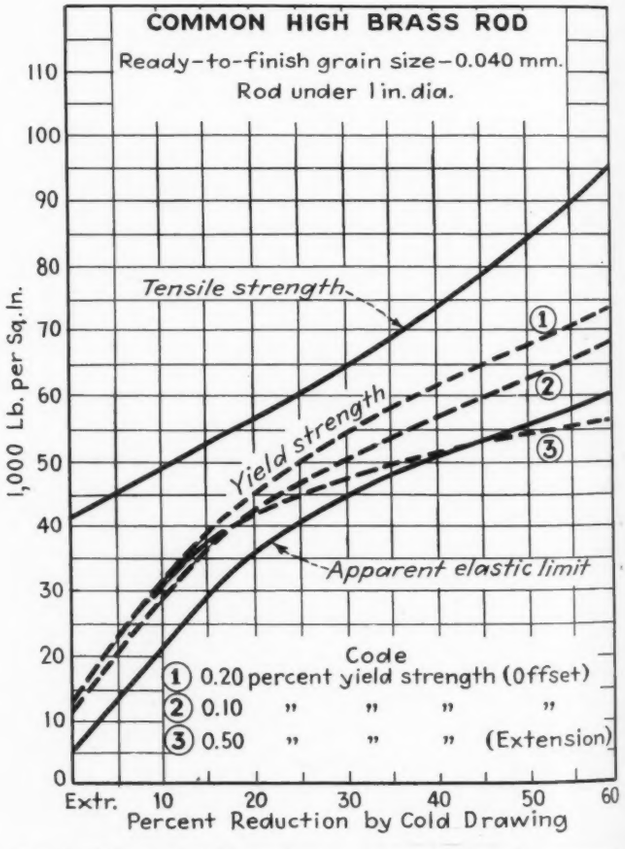

COMMON HIGH BRASS ROD
Ready-to-finish grain size–0.040 mm.
Rod under 1 in. dia.
1,000 Lb. per Sq. In.
Tensile strength
Yield strength
Apparent elastic limit
110 100 90 80 70 60 50 40 30 20 10 0
Code
1 0.20 percent yield strength (Offset)
2 0.10 " " " "
3 0.50 " " " (Extension)
Extr. 10 20 30 40 50 60
Percent Reduction by Cold Drawing

Fig. 3—Effect of cold working on tensile strength, apparent elastic limit and yield strength

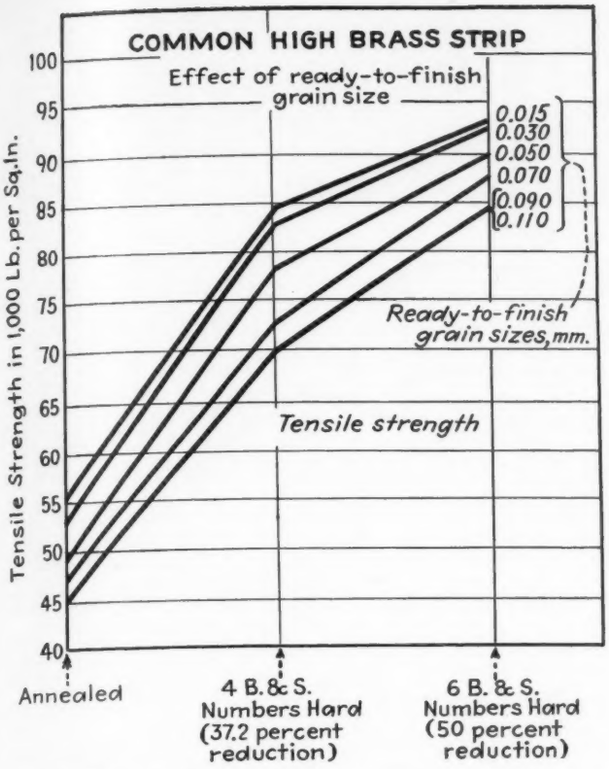


Fig. 4—Effect of ready-to-finish grain size on tensile strength of brass strip

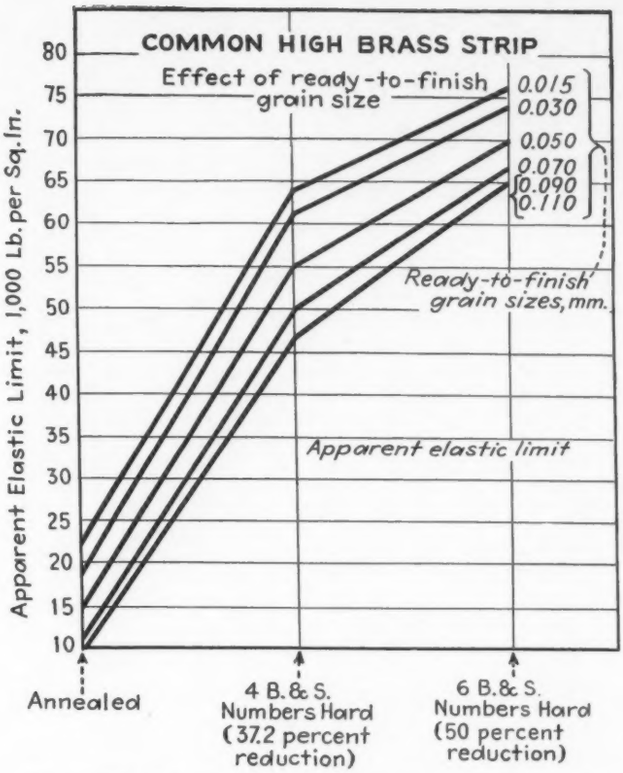


Fig. 5—Effect of ready-to-finish grain size on apparent elastic limit of brass strip

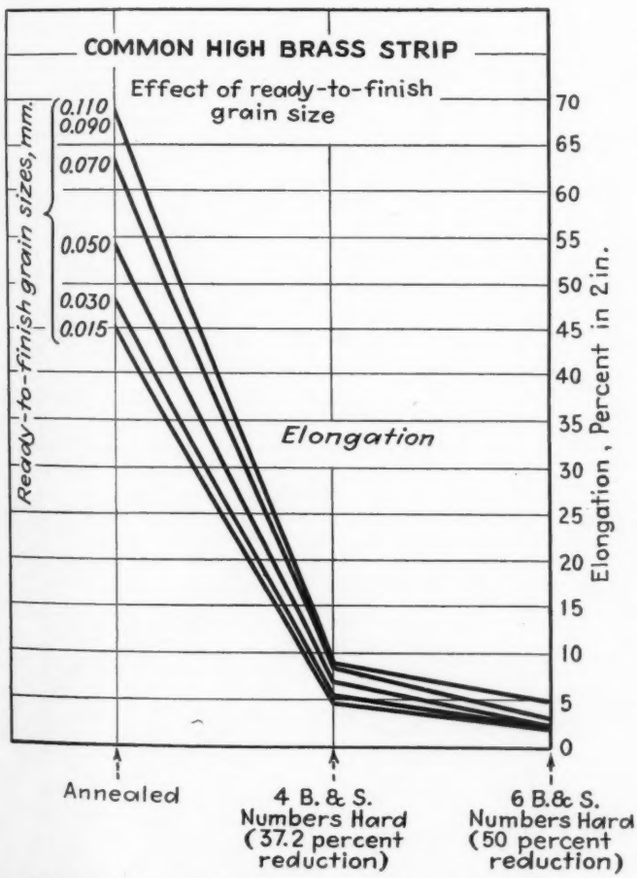


Fig. 6—Effect of ready-to-finish grain size on percentage elongation of brass strip

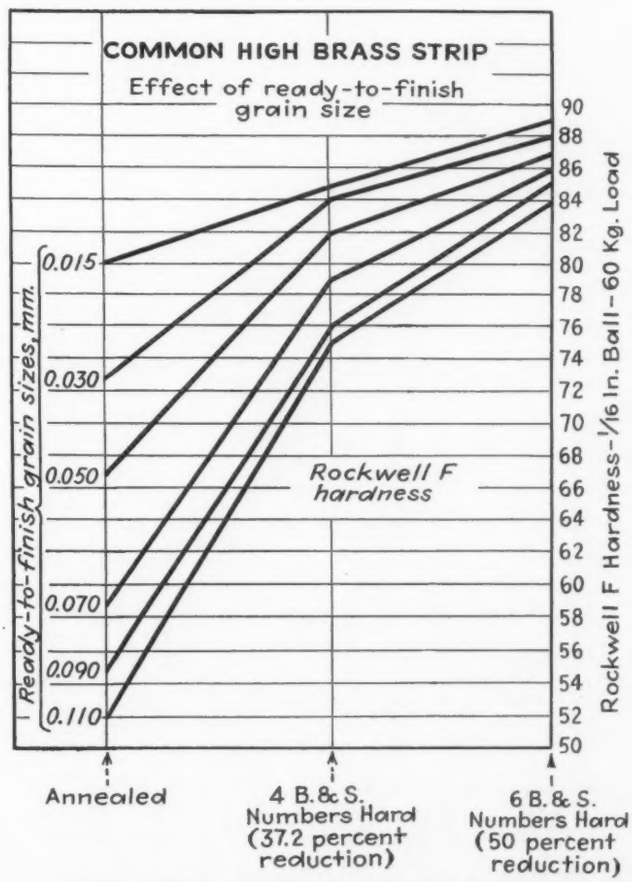


Fig. 7—Effect of ready-to-finish grain size on hardness of brass strip

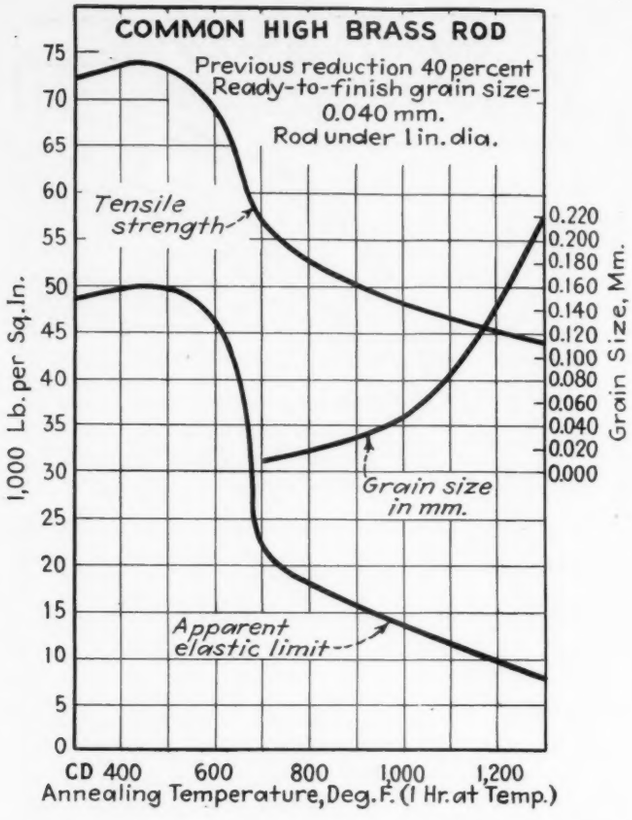


Fig. 8—Effect of annealing on tensile strength, apparent elastic limit and grain growth of brass rod

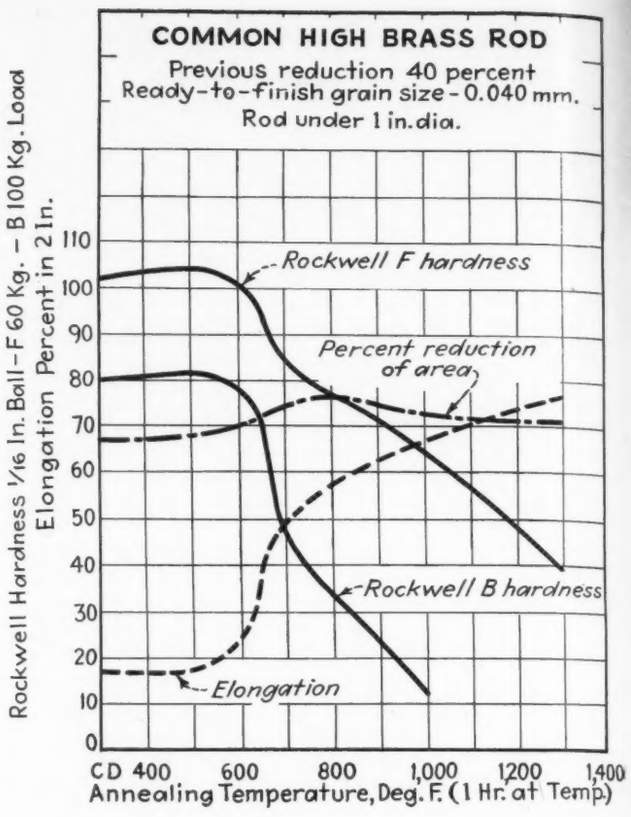


Fig. 9—Effect of annealing on Rockwell hardness, F and D, reduction of area and elongation of brass rod

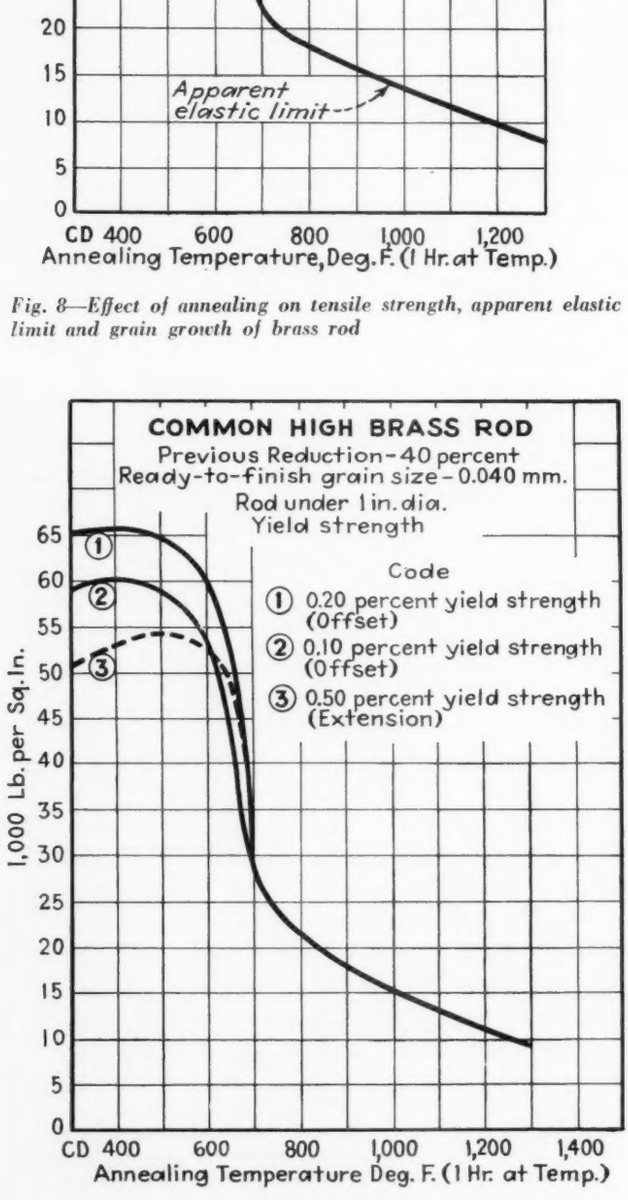


Fig. 10—Effect of annealing on yield strength of brass rod as determined by three different methods

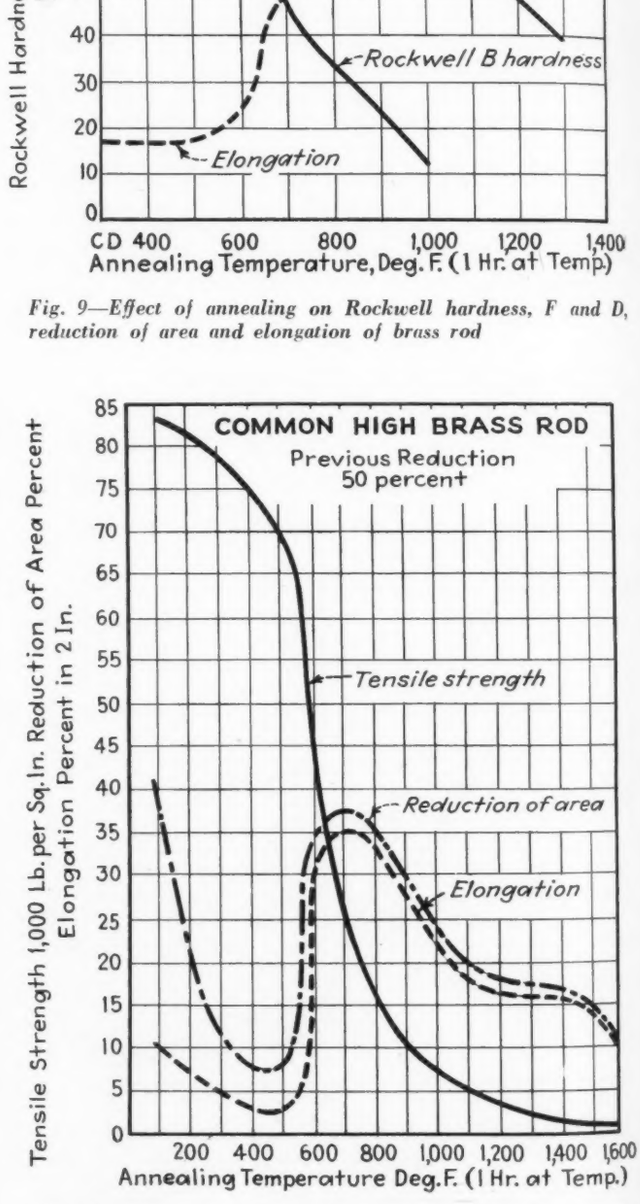


Fig. 11—Effect of annealing temperature on tensile strength, reduction of area and elongation of brass rod

Question and Comment

How to Calculate Two Bends in One

To the Editor:

The draftsman frequently runs into this kind of problem. Usually it is a pipe bending problem though the accompanying solution may be found to apply to other cases.

Fig. 1 shows a pipe on a hillside where an abrupt break occurs, at which point there is also a lateral bend. In all cases it is assumed that the slopes or angles of the sections above and below the bend are known. From these the angles made by the axes of each section to one another in any one plane can be found.

Now assume that the section on one side of the bend line is horizontal, the other section having the same relative angles to it as are required. The angles in plan and elevation are known. Angle B is the angle in plan. Angle S is the angle of slope to the horizontal.

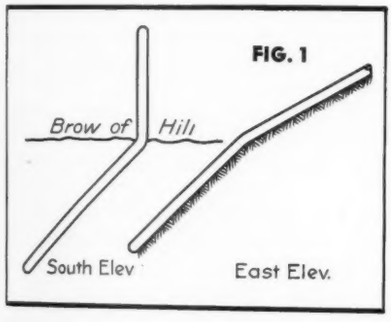


FIG. 1

Angle A must be found. From A and B, angle C can be computed and the length d found.

Now the pipe is revolved until the leg d is horizontal and the angle D can be computed.

By using unity as a base for the triangles the problem can be worked with the following formulas since $a = \tan A$, $b = \tan B$ and $d = \tan D$. The bend angle required is 180 deg. $- D$ deg. The diagram illustrates this.

WILLIAM SPENCER
Tooele, Utah

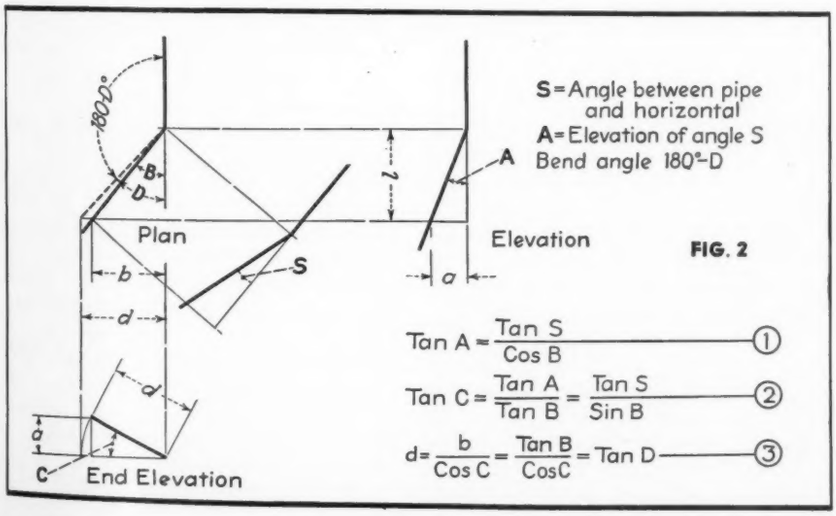


FIG. 2

Comments On "Difference Calculus"

To the Editor:

The article "Difference Calculus" by Professor Church on pages 13–15 of PRODUCT ENGINEERING is of the first importance. The writer has often felt that this method of calculus by finite instead of infinitesimal differences should be more widely used by designers. This process is often called "tabular integration", and is commonly employed by mathematicians when the infinitesimal calculus becomes too complicated.

The following comments may help the average busy designer in putting Professor Church's article to practical use:

(1) The list of symbols should include S = slope of the elastic curve.

(2) In the derivation of the equations for Fig. 1, d^2y/dx^2 equals the rate of change of slope, or curvature. The first integration therefore gives the slope dy/dx or rate of change of deflection. The second integration therefore gives "y" or the actual total deflection.

The curvature at any point on the elastic curve depends only on the moment Px at that point, divided by the flexural rigidity EI at that point. The fact that I has other values at other points does not affect the curvature at the point in question, but it does affect the slope, which is the collective effect of the curvatures all along the beam up to the point in question. Therefore, the first integration must treat I as a variable, thus:

$$\frac{dy}{dx} = \frac{P}{E}\sum\frac{x}{I}\,\Delta x$$

whence the final equation would read as follows:

$$y = \frac{12P}{E}\sum\Delta x\sum\frac{x}{bt^3}\,\Delta x$$

The equation given by the author would be correct only where the moment of inertia I was constant, which is certainly not the case in his Fig. 1.

(3) In the derivation of the equations for Fig. 2, the third derivative d^3y/dx^3 expresses the rate of change of curvature, and the second derivative d^2y/dx^2 expresses the curvature. Both the curvature and the rate of change of curvature at any given point depend on the value of I at that point only, so that the author has correctly treated I as a constant.

However, in performing his second integration to get dy/dx or the slope, the author has correctly treated I as a variable, as should have been done for the equations of Fig. 1.

In general, for the average designer, it is better not to pull these design factors E and I out of their normal place in the final equation for deflection. The saving in computations is outweighed by the chances of error and by the confusion of such concepts as "function of the ordinates" and "function of the slope" and "function of the moment of the areas" and "a measure of the distance"—all of which have to be evaluated in the last column anyhow.

The final equation for deflection if

written

$$y = \sum \Delta x \sum \Delta x \frac{1}{EI} \sum V \Delta x$$

would give actual moments, actual slopes, actual slope deviations and actual deflections at all points in the computations, and would be applicable without change of procedure to shafts of combined circular, square and rectangular cross-sections, and of different materials welded together along the shaft length.

(4) In actual practice, the shaft is never as stiff as calculated due to the sharp fillets and other sources of stress concentration. For example, in Fig. 2, the effective length of the 1¼-in. diameter section is not 6 in., but less than 5½ in., due to the idle unstressed metal at the corners where $x = 11$ and $x = 17$.

Due to the importance and usefulness of this article, the corroboration by the author of the above correction, undoubtedly an oversight, would be greatly appreciated by the many readers faced with calculations of this sort.

—ROBERT E. BRUCKNER

Can You Work This One?

H. E. SMITH

This month's problem—

Philanthropic Fairy Tale

During the late unlamented depression the philanthropic merchants of a small town agreed that, on a certain day, each would give his first customer as much money as he walked in with. One early bird with much to buy was first in three successive stores and spent $10 in each, after which he had no money left. How much did he start out with.

Solution to February problem—

The Law Wins Again

Our weary district attorney finally solved the murder of Bert Spanolli in Hoboken by finding the one false statement of the four statements made by each of the five suspects. The following are the false statements:

Slim—Shorty is the guilty man.

Tony—Joe lied when he said he never owned a revolver.

Red—I never saw Slim before now.

Shorty—I never saw Joe before now.

Joe—I did not kill Spanolli.

Hence the police put the handcuffs on Joe.

The January problem, which was varied in February so that the 25 lb. difference depended on whether a quantity of nickel was divided so that company *A* got 20 percent more than *B* or *B* got 20 percent *less* than A, involves a bit of algebra. It can be stated that

$$120x + 100x = 220x = \text{sum}$$

Also $100y + 80y = 180y = \text{sum}$

And $100y - 120x = 25$ lb.

$180y - 220x = 0$

Hence $1800y - 2160x = 450$ lb.

$1800y - 2200x = 0$

$40x = 450$ lb.

$x = 11.25$

$220x = 2475$ lb.

Thus the total amount of nickel was 2475 lb.

Case Histories in Patent Law

H. A. TOULMIN, JR.

NO. 27

QUESTION: Can a joint application after it is filed in the Patent Office be converted into an application of a single inventor?

ANSWER: If an innocent mistake has been made by joining two or more inventors as the co-authors of an invention, this mistake can be remedied. For many years this was not the rule, but in 1920 in a case entitled, In re Roberts, 263 Fed. 646, a father and son had been joined as joint inventors through a misunderstanding of the law. It later came out that the father only was the inventor. The Patent Office declined to permit this innocent mistake to be corrected but it was reversed by the Court of Appeals. In this case the Court said:

". . . . . To prevent a possible failure of justice, the present application should have been considered as a continuation of the abortive application. As already suggested, we perceive no reason why the mistake could not have been rectified by a simple amendment, but in any event the sole inventor should not be deprived of his day in court by raising of artificial barriers against him. He claimed his invention, and, through mistake, gave his son credit where no credit was due. The elimination of the son ought not to deprive the father, the sole inventor, of the benefit of his original application; and we so rule."

So now the rule is that an innocent mistake in inventorship can be remedied.

The whole question of joint inventorship is a most difficult one. If the several workers on an invention each contribute separate parts to the idea, and the result is a joint one so that you cannot tell where one man's work started and the other stops, then this is true joint inventorship. But if each one offered an idea and the resulting patent was merely the sum of their ideas, then it would not be joint inventorship. It is about the same difference that exists between invention and aggregation. There must be a true combination of thought between joint inventors, but in case of doubt, it is better to make the interested persons joint inventors because any honest error can always be corrected by the filing of a continuation application in the name of the correct inventor with the benefit of the original filing date.

In determining this inventorship question, particularly in engineering departments where a number of men work on a single project, it is a wise course to keep a record of each man's suggestions and contributions to the main idea.

The general rule is that the person directing the development is presumed to be the inventor. Therefore, any individual features of a total machine or process may be suggested by various engineers, but the credit for the total invention should go to the director of the work. This does not mean some remote chief engineer who only has a casual knowledge of it, but it means the man directly in charge of the development on that particular invention is presumed, in case of doubt, to be the inventor.

In Minerals Separation v. Hyde, 242 U. S. 261, Mr. Justice Clarke said:

"The claim that the patentees of the patent in suit are not the original discoverers of the process patented because an employee of theirs happened to make the analyses and observations which resulted immediately in the discovery, cannot be allowed. The record shows very clearly that the patentees planned the experiments in progress when the discovery was made; that they directed the investigation day by day, conducting them in large part personally and that they interpreted the results."

News and Summaries

Selenium and Tellurium Now Valuable Metals

THE SEMI-RARE METALS, selenium and tellurium, in the past often considered valueless to engineering metallurgy, are now valued members of the family of engineering materials. Selenium, produced last year at the rate of a million pounds yearly, is photosensitive, that is, its electrical resistance varies with the amount of incident light. As a result it is used in a large group of photocells.

Its property of passing electrical current in one direction only when connected to another metal such as iron make it useful as a dry plate rectifier, now widely used.

The glass industry uses about 100,000 lb. of selenium yearly to eliminate the greenish tint caused by iron compounds and to produce pink and ruby glass. Best quality glass tableware, tail-lights and signal lenses all require selenium.

Selenium, according to results obtained in recent years, is one of the best insecticides available for protection of citrus fruits, grapes, apples, corn and ornamental plants such as roses.

The cadmium sulfoselenide pigments known as cadmium reds and oranges are formed by calcining selenium with cadmium sulfide. Their brilliant colors and stability to heat, chemical action and sunlight have had many applications, for example, the maroon finishes on modern automobiles.

Both selenium and tellurium, used in rubber, increase resistance to heat and abrasion and improve resiliency. Such rubber is also used as portable electric cable coverings in excavating, mining, welding and similar rough jobs.

About 200,000 lb. of tellurium was produced last year as a step in the process of refining copper, silver and gold. Selenium is produced by the same process. Tellurium when added to iron in the ratio of four grams to a ton, improves the wear-resistance of the surface of the finished casting. With a bit of tellurium added, lead and lead alloys actually increase in strength and toughness as they are rolled or stretched and have greatly improved corrosion resistance. Tellurium also acts to increase the hardness of tin.

Metal selenides and tellurides are used as hydrogenation and cracking catalysts for the conversion of heavy oils to motor fuels.

These developments place selenium and tellurium among the strategically valuable materials of today.

Priorities Further Westinghouse Progress

IN REQUIRING them to abandon strategic materials, Westinghouse reports, priorities have resulted in the development of several new, improved products. In looking for a coating for porcelain without zinc, nickel or other strategically valuable materials, Westinghouse discovered a glaze that increases the strength of porcelain more than 100 percent and makes it easier to manufacture and more resistant to weather as well. The insulator shown under test has been coated with the new glazing material.

Another new product still being developed by Westinghouse is a preformed plastic made of wet pulp and resin. This is first formed in approximately the shape desired and then baked under pressure to harden the resin. This material has the strength of laminated plastic and the forming ability of the molded type.

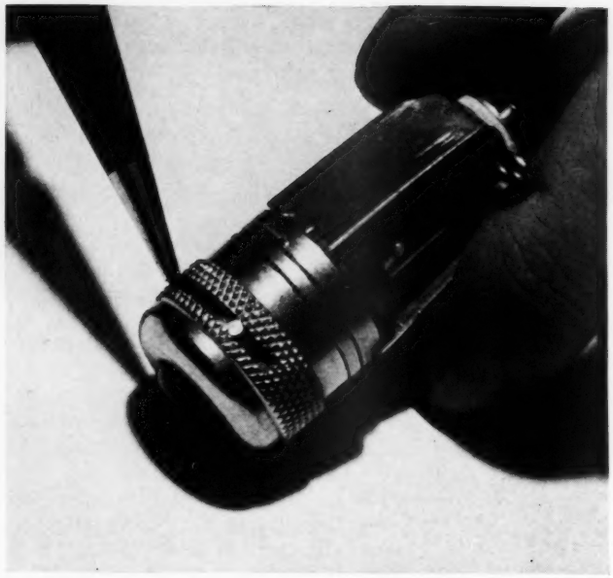
Molybdenum and a small percentage of tungsten in steel has been found to give high speed cutting tools of quality equal to that of high tungsten steels and much cheaper. These tools are now being used in Westinghouse's East Pittsburgh plant.

Scotch Tape Goes to War

"SCOTCH" TAPE, the draftsman's friend, is finding many unusual uses in the present emergency. There are a dozen or more companies making "scotch" tapes and industrial tapes of all sorts and all are expanding production to meet the demand.

Besides the now familiar use of tape on windows to minimize air-raid damage, such uses as masking of wing and car surfaces for painting of insignia or masking of polished metal surfaces for blast-etching of designs have become

New glaze on Westinghouse porcelain insulators more than doubles their strength



Knurled ring on this airplane panel indicator light can be turned to cut its needed daytime brilliance to a faint nighttime glow. The ring rotates one of two Polaroid screens 90 deg. out of phase with the other, eliminating the bulky rheostats previously used.

High-powered aircraft generator, built by Westinghouse Electric & Mfg. Company, has only twice the size or weight of the standard automobile generator below it but has 35 times the power. It delivers 5.7 kw. at 28 volts and weighs only 42 lb.

increasingly important. There are even tapes that can be used under a water spray or in a drying oven.

One manufacturer uses scotch tape for an assembly conveyor to which machine gun bullets stick until removed. Colored tapes are used to identify airplane wiring circuits. Other tapes seal bomber-flares from the effects of damp, salt ocean air or cover parachute release springs to protect the fabric from tearing and abrasion or are placed over the muzzle of an airplane machine gun to prevent corrosion of the barrel interior until the moment the gun is fired.

Its well-known use as a replacement for thumb tacks in the drafting room, expanded though it may be, is but a small part of its present usefulness.

Permanent Magnet Alloys Further Improved

NEW ALLOYS for permanent magnets are about thirty times better than the best carbon steels used a decade or more ago, William E. Ruder, head of the metallurgical and magnetic section of the General Electric Research Laboratory, disclosed recently. Part of this advance has been achieved by heating the magnet material and then slowly cooling it in the field of a powerful magnet.

Until about 1930 permanent magnets, which have many applications in electrical equipment, were made of alloy carbon steel. Then alloys free from carbon were devised. Some of the most effective are those known as Alnico.

The latest Alnico, an alloy generally consisting of iron, aluminum, nickel and cobalt, was first proposed by a laboratory in Holland and developed by the General Electric Research Laboratory. This may contain a small amount of copper as well. With magnetic cooling, its maximum energy is about five times greater than that of the best Alnico alloys of a few years ago.

The new Alnico contains a higher percentage of cobalt than the old, making the cost per pound relatively high. However, the high energy content with the resultant saving in size brings the cost per unit of available energy to a figure quite comparable with the other Alnico compositions.

Meetings

American Society for Testing Materials—Committee Work and Spring Meeting, Mar. 2–6, Hotel Cleveland, Cleveland, Ohio.

American Society of Mechanical Engineers—Spring Meeting, Houston, Texas, Mar. 23–25. C. E. Davies, secretary, 29 W. 39th St., New York, N. Y.

Ernest G. Stout Wins Sperry Award

THE LAWRENCE SPERRY AWARD for a notable contribution made by a young man to the aeronautical sciences was presented to Ernest G. Stout of Consolidated Aircraft Corporation, by the Institute of Aeronautical Sciences at its Honors Night Dinner at the Waldorf-Astoria in New York on January 27.

Mr. Stout, who is 28 years old, is a graduate of New York University and is now engineer in charge of aerodynamics and flight testing at the Consolidated Company. He receives the Sperry Award for 1941, including an honorarium of $250 with the citation. "For his contributions to the experimental determination of the hydrodynamic stability of model flying boats and sea planes." His research on small test models has been a considerable aid to engineers in designing today's large naval and commercial flying boats so that their performance at landing and take-off from the water is accurately known before the test flights.

Do You Know That—

Plants making magnesium from sea water needn't fear shortage of materials; there are about 4½ million tons of magnesium in a cubic mile of sea water. (5)

ENGINEERING IN WASHINGTON

McGRAW-HILL WASHINGTON BUREAU, *PAUL WOOTON, CHIEF*

Conversion of the auto industry to airplane and munitions production is not only the engineering project of the month; it will be an epic of the 20th century—to be read after the war. To make sure of putting the industry's 1500 plants and 350,000 machine tools to maximum effect in the war, WPB Chairman Donald Nelson sent Mohamet to the mountain—Ernest Kanzler, with unlimited authority from the President through Nelson, is directing the job, in Detroit. It is one of the few big war enterprises that does not get its orders from Washington.

We had to decide, as a nation, whether to take time to build new plants to make war gear, or convert our peace goods plants and do without their output. The decision wasn't hard to make, because if we had taken time to build plants, the Axis would have taken *us*. The auto plant conversion, in time to deliver its share of what the President wants in 1942, will be the next thing to passing a miracle. Kanzler is working out a four-point plan: tooling information service; machine tool listing service; contract distribution service; and technical information section. Under this plan, Chrysler can call on General Motors, or vice versa, to make tools. All competition is out, and personal squabbles are supposed to be.

What goes on now is little more intriguing than what will come out of Detroit after the war. Everybody in industry is getting into somebody's else field. Much of the knowledge gained will be of little post-war value; nobody will want tanks or guns or ships for quite a while. But they will want automobiles and airplanes. Facilities for making these two things are being completely scrambled. It will be each for himself and the devil take the hindmost. Certainly the auto people will build planes, and don't be too surprised if the airplane people turn out a gorgeous aluminum car.

You may have noticed in the newspapers a number of futuristic airplane pictures from Wright Field, the Army's air laboratory. Of course all those pictures were of planes the Army is *not* going to work on. The real ones are still behind guards and doors. But the released pictures do show that the Army has been doing a lot of thinking about pusher design. A wide arc of fire in front, uninterrupted by propeller disks, is very much wanted, and so is the unburbled flow of air which you get with pushers. Many persons have forgotten that the Bell Airacuda, a twin-engined all-purpose combat pusher, was a marked success, and that it was shelved, after a group of 13 planes had made a nice test run, only because at that time we were in a dither to get out the Bell Airacobra fighter for ourselves and the British. The Airacuda is one well-developed major pusher project, and the Northrop all-wing is another one. In pusher design we are far ahead of all other countries, and what we may do in this line is worth watching.

Improvements on the camera system of measuring airplane performance—acceleration on takeoffs, speed, rate of climb—have been made by CAA. The new system has been established at Long Beach, Burbank, Los Angeles Municipal, La Guardia, and St. Joe, Missouri. A 16mm. movie camera is set up at a point midway and 1500 feet from the runway. Stakes driven along the runway at intervals appear in the picture. The measurements are made on a screen grid. Four cameras are used in a different way on seaplanes and flying boats. Civil Aeronautics Authority has a manual on the subject.

Diamond dies have previously been bored by poking at them with continually sharpened needles for hundreds of hours. Now they are scientifically drilled in whole groups, with new visual inspection aids and high speed electric motors, by craftsmen who have learned in weeks what used to take a lifetime. America has always been able to meet its own requirements in dies larger than a tenth of an inch but the new production turns out dies measuring a quarter the diameter of human hair to below .0008 in. The dies are used for drawing fine wire for aircraft instruments, high frequency radio tubes, resistance wire in measuring instruments, electric lights, and inner workings on dashboards of tanks and bombers.

Processing tin cans for use in boosting copper mine production is started as WPB announces that three plants will be located in the Southwest. Cans collected in a scrap drive will be cleaned and shredded in the processing plants and the metal sent to copper mines. There, mine waters containing copper sulphate will be permitted to flow over the shreds. A chemical reaction results in deposits of copper. It is estimated that processed cans can extract 2,000 pounds of copper a month from the mine water.

Zinc and brass die castings to save aluminum in the manufacture of artillery fuses is being discussed by War Production Board. Brass, steel and zinc castings already are being used in some fuses, but it is likely that more extensive substitutions can be accomplished. The change from aluminum to either brass or zinc affects ballistic properties and, in an accurate mechanism such as a fuse, failure to function properly might result in serious consequences. It is necessary to make up samples of brass and zinc castings and test them extensively prior to actual use.

Elimination of all aluminum in purchases of field range equipment, pack saddles, ration boxes and coffee filters by the War Department is expected to save over 16 million pounds yearly. Each ration box contained about 14 pounds of aluminum; coffee filters, over 9 pounds; pack-saddles, 7 pounds. Hereafter, the pots and filters will be steel and the frame of the saddle will be plywood or plastics.

Don't be misled by reports on current conversion. There will be more *new* munitions plants—plenty of them. More money has been appropriated or budgeted for new plant capacity since the beginning of the year than all the pre-Pearl Harbor expenditures put together. Pre-war total was about six billions; new money totals more than seven billions.

World's biggest wind will blow at the Moffett Field laboratory of the National Advisory Committee for Aeronautics. Pittsburgh-Des Moines Steel Company has the job and has scheduled for completion early in 1943 an enormous wind-tunnel costing $5,000,000, standing 200 ft. high, 900 ft. long, and 400 ft. wide. Specifications call for completion in 900 days, working 500 men. The structure will cover 10 acres.

New Materials and Parts

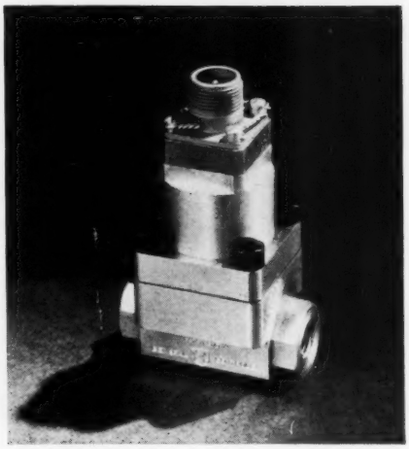
Shatterproof Rheostats

Ceramic insulators have been replaced by a molded synthetic resin in a new type of rheostat for aircraft and ordnance applications. Here the units not only have to withstand conditions

of high humidity and temperature extremes but also the concussion of gunfire. Manufacturers state that the new rheostats are lighter in weight than others, have a 50 percent lower temperature rise for equal size in other types, and are available in both 25- and 50-watt sizes to meet the 200-hour salt spray test requirement. Covers are available to protect units from dust and dirt. International Resistance Co., 401 N. Broad St., Philadelphia, Pa.

Electric Valves

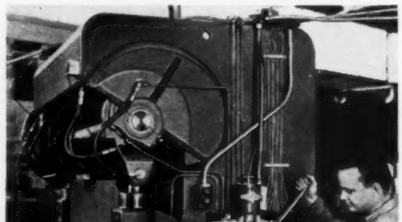
Designated as Series PV, a new line of electric valves has been designed for positive valve operation on moving equipment and vibrating machines such as airplanes, buses, tanks, railroad cars, ships, machine tools, etc. Of the two-wire current failure type, designed for compactness and low weight, manufacturers claim these valves will handle all types of liquids, gases and vapors, including refrigerants, greases, gasoline, alcohol, anti-icing fluids, etc., under pressures from a fraction of a pound to 1,500 lb. Additional advantages claimed are drip-proof design, positive operation in any position regardless of substantial increases in acceleration, and minimum current consumption. Application of these valves to airplanes is said to make it possible to save weight



and simplify many tubing and piping arrangements, for they often weigh little or no more than units they replace and eliminate heavy operating gear. General Controls Co., 801 Allen Ave., Glendale, Calif.

Lubricating System

In the Centro-matic system for lubricating bearings, individual lines run from the centralized pump to injectors for each bearing to be lubricated. Each injector, connected to the bearing by tubing or flexible high pressure hose as required, is individually adjusted to discharge the required amount of lubricant. In the illustration, the Centro-matic installation is the new 2-lb. pump. It is easily mounted on the machine, and a few strokes of the handle delivers the lubricant to all bearings. Pumping units with drum capacities up to 400 lb. are available, and the system can be



electrically operated with push-button control or entirely automatic with time-clock control. Lincoln Engineering Co., 5701 Natural Bridge Ave., St. Louis, Mo.

Dynamic Balancing Unit

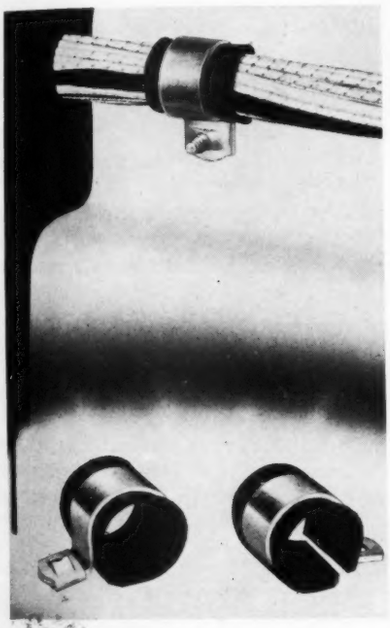
A portable dynamic balancing unit known as Type HQ consists of a sensitive wattmeter assembly, a sine wave generator, a velocity type vibration pick-up, and the necessary connecting cords. It may be used over a speed range of from 600 to 10,000 r.p.m., and by an auxiliary attachment the range may be extended down to 100 r.p.m. Producing a voltage whose amplitude is proportional to the vibration measured, the pick-up has a fixed phase angle relationship with the vibration for a fixed frequency. The sine wave generator produces an adjustable phase, sine wave current supply, the frequency of which coincides with the r.p.m. of the machine being balanced. Its field is a 2-pole rotating magnet directly coupled to the machine rotor. Adjustable angularly by hand, the stator has

two windings 90 deg. apart electrically that facilitate angle and amount observation. Metering unit is essentially a specially designed double scale, highly damped dynamometer type wattmeter calibrated in arbitrary units. To balance a rotating machine, the sine wave generator is coupled to the shaft of the rotor. Held against some part of the frame, the pick-up produces a voltage the amplitude of which is proportional to the vibration being measured.

Voltage generated in the pick-up coil varies directly as frequency and amplitude of the vibration. Amplitude and vibration phase angles are indicated on the wattmeter. Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

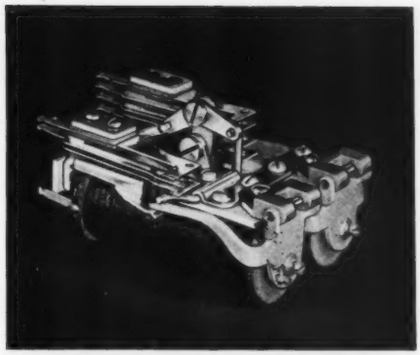
Wire Fastening Device

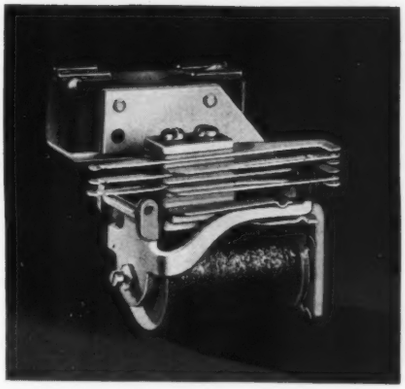
Kwik-klip, a new device for wiring installations, is constructed as a half loop which fits over the wire or conduit. Clips are supplied with or without Speednuts, with or without neoprene cushions. When the latter are supplied they are permanently mounted to the clamp with the Thermo-weld process, eliminating the need for wrapping wire or conduit with tape for protection at the point where the clamp is applied. Sizes range from ⅛ to 1¼ in. Bendix Aviation, Ltd., North Hollywood, Calif.



Two New Relays

Remote controlled starting and stopping of radio transmitters and receivers, drainage pumps, or other apparatus, is the function of the "start-stop" relay (top photograph). Known as "Type 19," this relay operates and releases over two wires, with a common return. The electro-mechanical locking arrangement supplies proof against false operation or release under all conditions of shock. Also, operation is said to be unaffected by any normal temperature range, from −22 to +131 deg. F. All contact springs have twin contacts of precious metal. The relay can be supplied with a maximum of 18 springs for control purposes. The lower illustration shows the "Type 17" relay,





a small, light-weight unit for d-c control of a-c circuits. Contacts are snap-action-single pole, arranged to open, close or switch circuits when the relay operates. They will make 1,150 watts, break 690 watts, at 115 volts, a-c. Unit measures 2¼x2¼x2½ in. Manufacturers recommend this relay especially for conditions of extreme humidity or vibration. As coils are impregnated with insulating varnish, relays are said to be unaffected by 95 percent humidity. Such impregnation also prevents movement of windings under vibration. All screws are locked into a rigid assembly, and adequate mount holes permit secure fastening. The Type 17 relay is supplied in one or two snap-action contacts or with one snap-action contact and one contact spring assembly (up to 10 springs). A choice of contacts is offered. Automatic Electric Co., 1033 W. Van Buren St., Chicago, Ill.

Fixture Studs for Bar Hangers

So that junction boxes may be attached with a single operation, fixture studs have been developed for bar hangers, both standard and S-shaped, which

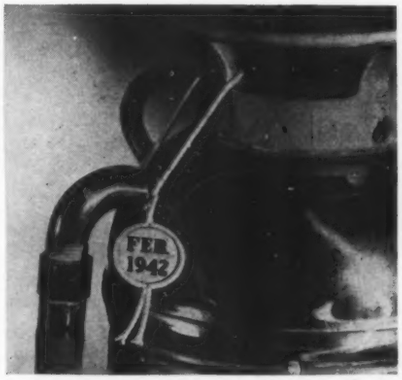
formerly were supplied with two-operation studs. As two, small, self-locating lips take the place of the lock nut formerly used, wiring room in boxes is saved. Boxes may be tightened or easily re-set on the bar with a screwdriver. General Electric Co., Bridgeport, Conn.

Special Paints

Paints for blackout or camouflage, luminous paints and traffic paints are among recent developments. Recommended for use on exteriors of windows and skylights, the blackout paint forms a permanent, elastic, non-reflecting film that will not wash off because of atmospheric conditions or moisture and temperature conditions inside the plant. It may also be used on wood, metal, concrete, etc. Camouflage paints, in standard colors adapted for that purpose by Army engineers, have the non-reflecting flat finish necessary. Of non-penetrating type, and easy to apply, they can be used in one-coat finishes on all type of surfaces. As luminous paints are both fluorescent and phosphorescent, they serve for blackout installations or as markers for strategic points in industrial plants, public buildings, or air raid entrances. Vita-Var Corp., Newark, N. J.

Safety and Inspection Seal

Tamper-proof safety and inspection seals not only guarantee against tampering, alteration or substitution but also allow identification markings. They are made of two components, the

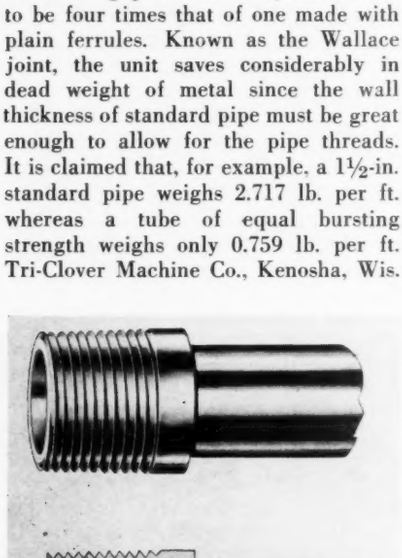


pre-shaped metal seal-cup and the multi-color identification disk. The advantages of multi-color disks is that in addition to carrying identification information, basic colors indicate such elements as time, process, location, etc. Further markings such as inspector's number can be incorporated in the sealing pliers so that at the moment of closing pliers the number or marks are indented into the identification disk. Permanently applied with either string,

thin cord or two-ply wire, seals cannot be used once they have been removed. Stoffel Seals Co., Inc., 188 Water St., New York, N. Y.

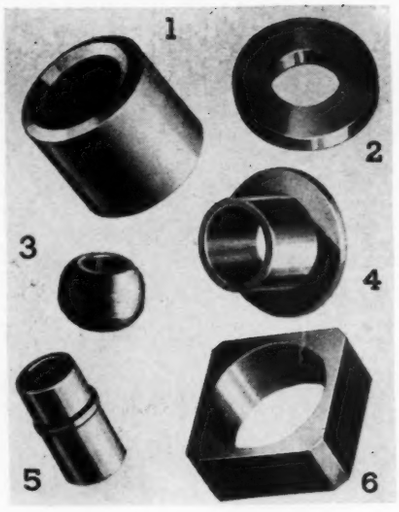
Pipe Joints

To permit the use of standard thin wall tubing in connection with standard threaded iron pipe size fittings of all kinds. This new joint consists of a threaded ferrule within which the tubing is expanded to fill sharply and squarely machined grooves. The inner surface of the tube remains smooth, and the holding power of the joint is said to be four times that of one made with plain ferrules. Known as the Wallace joint, the unit saves considerably in dead weight of metal since the wall thickness of standard pipe must be great enough to allow for the pipe threads. It is claimed that, for example, a 1½-in. standard pipe weighs 2.717 lb. per ft. whereas a tube of equal bursting strength weighs only 0.759 lb. per ft. Tri-Clover Machine Co., Kenosha, Wis.



Self-Lubricating Iron Bearings

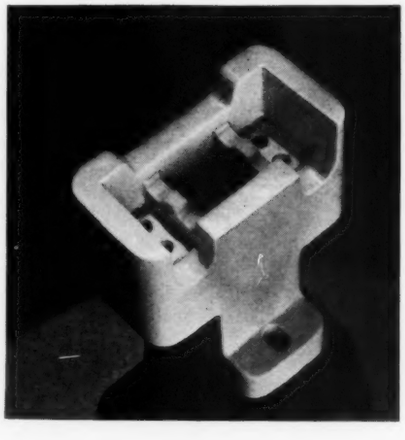
Stronger than porous bronze bearings, new porous iron bearings are said to be interchangeable with the former in most applications. Introduced to conserve copper, they are made from powdered iron, which is molded to size and shape desired, baked and saturated with oil. Their average porosity of 25 to 35 percent enables them to store a large amount of oil which, in many instances, lasts the entire life of the application, eliminating the use of oil or grease cups. Additional lubrication is recommended for heavy-duty or continuous operating units. Manufacturers state that because of a low friction coefficient and the self-lubricating qualities of the bearings, excessive temperature, speed reductions, noise and scoring of shafts are prevented. Called



"Selflube" porous iron bearings, they are supplied in both standard and special shapes as shown in the illustration in which (1) is a sleeve or plain cylindrical bearing, (2) a washer or thrust bearing, (3) spherical or self-aligning bearing, and (4) a flange bearing. Examples of special shapes are shown at (5) and (6). Keystone Carbon Co., 1935 State St., St. Mary's, Pa.

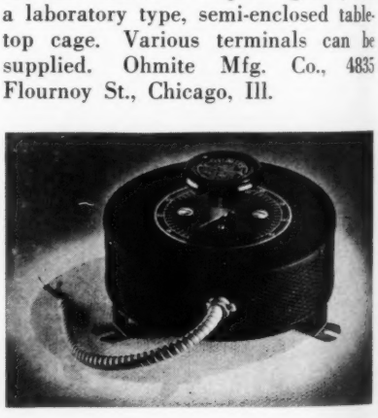
Ceramic Plastic

Called "Prestite," a new ceramic plastic, basically porcelain, may be formed into intricate shapes, will not distort at high or low temperatures and can be cored to produce complicated internal cavities. Information from the manufacturer states that its resistance to both thermal and mechanical shock exceeds that of ordinary porcelain and industrial glasses. Its impact strength is said to exceed that of ordinary wet process porcelain because no unrelieved internal stresses are set up at the time of forming. Heat as high as 800 deg. C. does not impair its mechanical strength or distort its shape. Since tolerances are guaranteed not to exceed $\frac{1}{16}$ in. per in. on any shape, regardless of size, the dimensional accuracy is equal to that of dry processed porcelain. Metals can be joined with Prestite surfaces by the Solder Seal method. Applications include valve seats for high speed pumps, coffee grinder plates and sandblast nozzles, indicating the ability of this material to stand up under punishment. Chemically inert, Prestite is not affected by weather or climate, alkalis, oils, gases, or acids other than hydrofluoric. Its dielectric strength, which equals that of the highest grade of wet processed porcelain, is retained through 200 deg. C. As repetitive flashover does not char or burn this material, the flashover voltage for any given piece remains constant under a given set of atmospheric conditions. It has been developed primarily for high strength installation, such as fused cutout boxes, switch locks, terminal covers and third-rail insulators, all of which require intricate design, great strength, and ageless life. Westinghouse Electric & Mfg. Co., Derry, Pa.



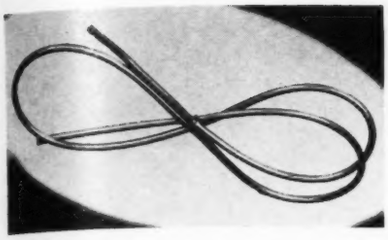
Rheostat Cages

A variety of rheostat cages has been developed for table top or surface mounting. Recommended uses are those in connection with fractional hp. motors, heating device controls, dental and medical equipment, and laboratory setups. Types available include ventilated cages with perforated sides (most generally applicable), dustproof cages, explosion proof cages, housing for rheostats in tandem, ventilated cages with one half closed as a splash guard, and a laboratory type, semi-enclosed table-top cage. Various terminals can be supplied. Ohmite Mfg. Co., 4835 Flournoy St., Chicago, Ill.



Extruded Insulation Tubing

With resistance to extremely low temperatures −30 to −40 deg. F., this plastic sleeve insulation is claimed to possess a dielectric strength of 23,800 volts, tensile strength of 3,140 lb. per sq. in., and an ultimate elongation of 255 percent at 2-in. gage length. Moisture absorption factor is said to be less than ½ of 1 percent in 24 hr. of



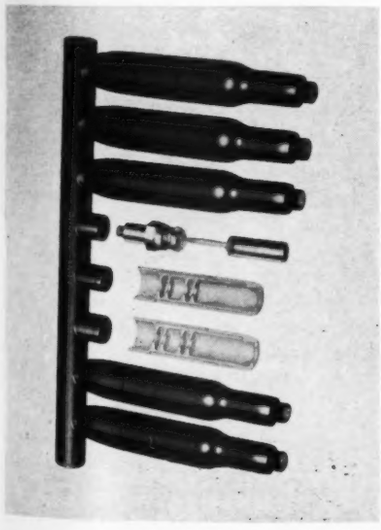
water immersion. In a variety of colors, this material can be obtained in standard A.S.T.M. diameters in 36-in. lengths or coils of continuous length in minimums of 25 ft. William Brand & Co., 276 Fourth Ave., New York, N. Y.

Electrical Timer

Measuring the total length of time a circuit is closed, the Model 17 Time Meter functions to record the life of machinery or machine parts. As the dial changes continually, always presenting an up-to-date record, readings may be taken at any desired interval. The unit is small, rugged, easily installed on any wall or panel, and readily attached to the ears of any standard switch box. Operation is on alternating current only—24, 115, or 230 volts, 25, 50, or 60 cycles. Cyclometer type dial has five digits, reading 00000 to 99999. Sangamo Electric Co., Springfield, Ill.

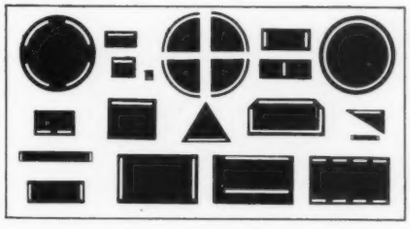
Network Connector

Designed for use in junction boxes of secondary networks, this new type of insulated connector provides a simple and compact means of interconnecting ties of the network, joining ties to the network transformers, and tapping off any number of loads. The connector, called a "Mole"; is a central conductor equipped with "Molimiters," current limiting devices of the fusible link type. An indefinite number of molimiters can be inserted in the central conductor body, and hence extra taps can be added without disturbing existing connections. In general, each limiter box contains four of the Mole assemblies, three with limiter protections for the three phases of the circuit, and a fourth —the neutral—which does not require limiter protection. Two of the types available are Type ZMEJ and ZMEH. The former, as shown, has extended ends which enable the connector to be supported on grooved insulated strips mounted in the limiter box. Type ZMEH has tapped holes on each end of the main conducting body for fastening to the insulating support by means of bolts. Furnished with any specified number of outlets, the design can be modified to suit individual needs. Burndy Engineering Co., Inc., 107 Eastern Blvd., New York, N. Y.



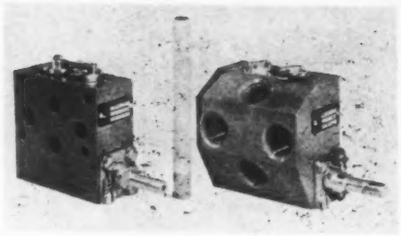
Photronic Dry-Disk Photocell

Stable, dry-disk photocells are now supplied in a wide variety of shapes and sizes, as shown, including multiple cell circuits on a common electrode. Developed to overcome the higher costs usually associated with specialty cell design, these cells can be furnished to meet exactly specifications as to output, resistance, spectral response, etc., regardless of the quantity involved. Photronic Div., Weston Electrical Instrument Corp., 614 Frelinghuysen Ave., Newark, N. J.



Hydraulic Selector Valve

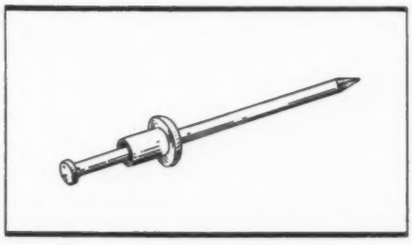
With identical component operating parts, the two designs of four-way hydraulic selector valve, shown with king-size cigaret, differ only in porting arrangement. The smaller unit is adapted for multiple assemblies and manifolding, and the larger unit is for individual installations with outlet ports independent of additional assemblies. Having ample capacity for landing gear actuation of typical bi-motored aircraft, the smaller assembly weighs but 8 oz., the larger 11 oz., representing savings of 83 and 76 percent in weight



as compared to predecessor units. Reduced weight and improved pressure drop characteristics are said to have been obtained almost entirely through design improvement and simplification. Bodies are fabricated from Dural bar stock to permit operating pressures up to 3,000 lb. per sq. in., with ample safety factor for momentary overload in excess of this value. Operating handle loads of as low as 60 lb. are provided for operation at 800 lb. per sq. in., with special cams for further reducing handle loads at higher operating pressures. The larger valve requires a space of $1\frac{1}{2}$x$2\frac{1}{4}$x$3\frac{3}{8}$ in.; the smaller slightly more than 1 in. in width by $2\frac{1}{4}$x$2\frac{3}{8}$ in. Adel Precision Products Corp., Burbank, Calif.

Hollow Rivet

A new type of rivet has been developed for one-man use in closed and blind assemblies, such as airplane wings, frames, and fuselage. Drawn from a punched disk, the rivet is then fitted over the shank of a common iron finishing nail. For fastening, the rivet is inserted into the hole, nail head first, and held in place as the nail is pulled through. This causes the head to expand the inside end of the rivet, tightening it down on the work. As the nail has been nicked below the head, the latter snaps off after it has done its



work. In production, a regular pneumatic hammer fitted with a chuck clamps the rivet against the face of the work and a claw extracts the nail. Rivets are made in Monel, aluminum and cold rolled steel, in 40 different sizes of various lengths, with diameters ranging from $\frac{3}{32}$ to $\frac{1}{16}$ in. and wall thicknesses from .018 to .027 in. Canadian Car & Foundry Co., Fort William, Ontario, Canada.

Books and Bulletins

Mechanical Properties of Materials and Design

JOSEPH MARIN—*273 pages, 6x9 in. Blue clothboard covers. Published by the McGraw-Hill Book Co., 330 West 42nd St., New York, N.Y. Price $3.50.*

In this book the author has ably shown by means of theory, experimental data and examples how to apply a knowledge of the mechanical properties of engineering materials to the design of structural and machine members under various conditions of simple and combined loads, as well as to withstand temperature effects. The author's main objective is to show that in modern design the selection of a material for a part or member can be best based on the mechanical properties of materials as determined by tests conducted under external conditions simulating the actual operating conditions to be encountered.

Design procedure and test methods for obtaining data are only briefly described. Various existing design codes and specifications are discussed. Designs of particular machine and structural members are presented to show how a study of recent theories will influence the required dimensions of the members. Working-stress and design charts are included to facilitate the use of data by the designer.

The Mathematics of the Shops

FRANK J. MCMACKIN AND JOHN H. SHAVER—*444 pages, 5½x8½ in. Illustrated with photographs and nearly 700 drawings; indexed. Blue clothboard covers. Published by D. Van Nostrand Co., Inc., 250 Fourth Ave., New York, N.Y. Price $2.50.*

Intended primarily for mathematics training in vocational schools, evening trade extension classes, apprenticeship classes and in classes of the National Defense Training Program. Material in this book will also be found valuable for demonstrating working application of Arithmetic, Algebra, Geometry and Trigonometry to high school classes. Shop terminology and drawings are used to excellent advantage in applying mathematics to machine, wood working and electrical shops and to the building trades. The authors' attempt to make the mathematics evolve from and apply directly to engineering and shop situations is highly successful. Included in the appendix are numerical tables, tables of weights and sizes, trigonometric functions, 4 place logarithms, formulae, and other tables such as basic thread dimensions and tap drill sizes.

It's About Time

PAUL M. CHAMBERLAIN—*490 pages, 7x10¼ in. Red clothboard covers. Published by Richard R. Smith, 120 East 39th St., New York, N.Y. Price $7.50.*

Replete with information interestingly set forth, this volume is concerned with the constructional evolution of watches and clocks. The author has admirably blended into his technical descriptions a warm human interest in the problems and personal ambitions of the men who have had a part in the development of timepiece mechanism. The book is an inspiration for further research work to all who make a hobby of watch collecting.

Engineers who are interested in the design of fine mechanical movements will appreciate the niceness of detail exhibited in the many excellent illustrations and line drawings.

The contents of the book are divided into three main parts. The first deals with the evolution and development of the variations in escapements. The second contains descriptions of watch regulators and unusual timepieces. The third is made up of biographies of fifty famous watchmakers.

Numerous references to articles and books throughout the subject matter form a splendid bibliography for further study.

Practical Arc Welding

W. J. CHAFFEE—*516 pages, 5½x8 in. Illustrated and indexed. Red leatherette covers. Published by Hobart Trade School, Inc., Box E W 80, Troy, Ohio. Price $2.*

A practical, informative work, this text book by the author of "Arc Welding and How to Use It" is a revamping of the original text to bring the subject up to date. In addition to the operator training course for which the material has been primarily assembled, there are chapters of general information—where arc welding is used, metals and alloys available for arc welding, strength of welded joints, cost, and other subjects relating to applications. Sections are devoted to carbon arc welding, "long arc" copper welding, definitions of welding terms (American Welding Society Definitions), and tabulated data of useful information. As well as serving as a student manual, this work will fulfill a reference requirement for design and production engineers.

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Patent Background for Engineers

54 pages, 8½x11 in. Published by Allis-Chalmers Mfg. Co., Milwaukee, Wis. Available free.

This collection of articles, originally published in the Allis-Chalmers Electrical Review, was written by the members of the patent department of the company. It is intended for engineers and laymen and is written in non-legal phraseology. Articles cover developing, recording and use of inventions and other such branches of the subject. The style is clear and, at times, lightly humorous and many illustrative examples are included.

Welding Procedures

54 pages, 8½x11 in., loose-leaf with paper covers. Published by Air Reduction Sales Co., 60 E. 42nd St., New York. Price 60 cents.

The reader is given the benefit of the publisher's experience in welding in a presentation of standard procedures and techniques to meet new problems in welding various materials in several types of jobs.

Grouped under the more commonly used metals and alloys are (1) recommendations of the best processes under different circumstances, (2) recommendations of filler metals for each process, and (3) a large number of hints and descriptions of specialized techniques not commonly known.

Appendices give electrode consumption data, gas welding rod consumption data, approximate gas consumption for oxy-acetylene welding, and forms for comparative welding record.

Hot Tinning "Difficult" Mild Steels

W. E. HOARE AND H. PLUMMER—*28 pages, illustrated, 6x10 in. Blue paper covers. Publication No. 107 by the Tin Research Institute. Obtainable from Batelle Memorial Institute, 505 King Ave., Columbus, Ohio.*

This booklet does a workmanlike job of analyzing the causes of "de-wetting" of mild steels and suggesting methods for curing these difficulties. While the first section, dealing with curative means, is of immedate use to engineers and shop men, the second and third sections are equally valuable. They deal with studies in methods of rectifying "difficult" steels and analyze the causes of "de-wetting" on the basis of numerous experiments which also suggest the curative methods.

EFFICIENCY OF WORM GEARS

A. C. RASMUSSEN

The efficiency of worm gears is usually expressed by the formula,

$$E = \frac{\tan \lambda\,(1 - f \tan \lambda)}{f + \tan \lambda} \qquad (1)$$

in which λ = lead angle of the worm
f = coefficient of friction

This formula can be solved more easily and quickly if written in a different form:

$$E = \frac{\tan \lambda}{f + \tan \lambda}\,(1 - f \tan \lambda) \qquad (2)$$

and then dividing numerator and denominator of the fractional part by tan λ:

$$E = \frac{1 - f \tan \lambda}{1 + f \cot \lambda} \qquad (3)$$

In this form, the values of the numerator and denominator are written out and the division of the numerator by the denominator can be done mentally with sufficient accuracy to enable quick trial of several values of λ without much effort.

The efficiency of worm gearing is generally calculated only when the worm is the driver. However, sometimes it is necessary to determine efficiency when the wormwheel is the driver, especially when it is essential that the drive should allow over-running, as with the rear axle of an automobile or truck. It is required also when the worm must be of the self-locking type, as with a boom hoist on a shovel or crane.

When the over-running type of worm and wormwheel is employed and efficiency is to be calculated, the following will help.

The lead angle of the worm is λ deg. Therefore, the lead angle of the wormwheel is 90 λ deg. The efficiency of the drive in reverse motion then is,

$$E_r = \frac{1 - f \tan (90 - \lambda)}{1 + f \cot (90 - \lambda)} \qquad (4)$$

Since $\tan (90 - \lambda) = \cot \lambda$ (5)

and $\cot (90 - \lambda) = \tan \lambda$ (6)

$$E_r = \frac{1 - f \cot \lambda}{1 + f \tan \lambda} \qquad (7)$$

When $\lambda = 45$ deg., $\tan \lambda = \cot \lambda$, therefore, $E = E_r$. When λ is less than 45 deg, E_r is less than E (i.e., efficiency is lower). When λ is greater than 45 deg., E_r is greater than E.

For a self-locking worm drive, it is apparent that E_r should equal zero.

Therefore $$\frac{1 - f \cot \lambda}{1 + f \tan \lambda} = 0 \qquad (8)$$

Whence $$1 - f \cot \lambda = 0 \qquad (9)$$

Solving for λ

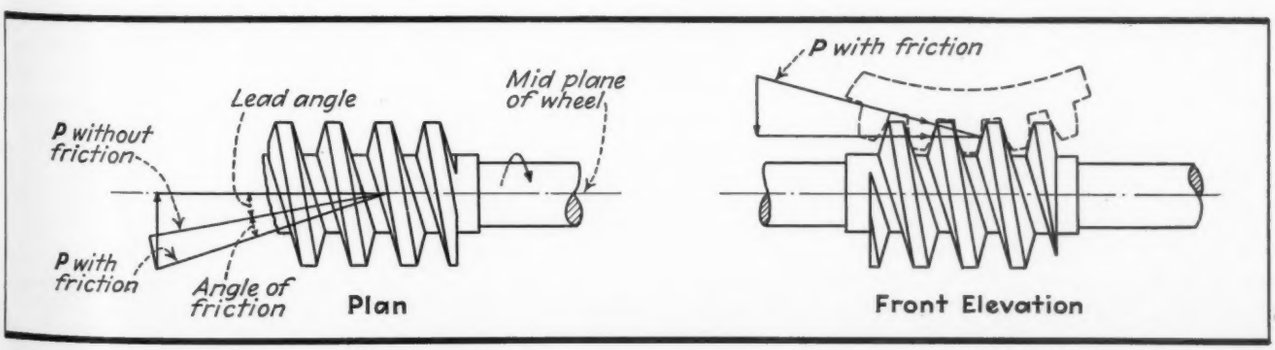
$$\cot \lambda = \frac{1}{f} \qquad (10)$$

$$\text{therefore } \tan \lambda = f \qquad (11)$$

When tan λ is greater than f, the drive will not be self-locking theoretically. Therefore, for self-locking tan λ should be less than f. When tan $\lambda = f$, the drive is just on the point of being self-locking. However, static friction is greater than sliding friction and if no vibration exists, the drive will be self-locking, sometimes even when tan λ is considerably greater than f. But when the drive is subject to impact or vibration, slippage or drifting will occur. A small ratchet pawl acting on a ratchet wheel on the worm shaft is sufficient to prevent drifting. A hand brake may also be used although not as efficiently.

These formulas cannot be considered as absolute because it is difficult to assume a correct value for f, but they show the characteristics required in a design.

On the following page are given the efficiency formulas for worm gearing for the two conditions of operation, namely, the worm driving and the wheel driving. The table of natural functions is given also to make it possible to carry out the computations completely without the need of referring to further tables.



EFFICIENCY OF WORM GEARS

A. C. RASMUSSEN

Formulas for computing the efficiency of worm gearing, both when the worm and wormwheel are drivers, are summarized with the following symbols:

E = efficiency when worm is driving.
E_r = efficiency when worm wheel is driving.
λ = lead angle of worm.
f = coefficient of friction.

When worm is driving, $E = \dfrac{1 - f \tan \lambda}{1 + f \cot \lambda}$ (1)

When wormwheel is driving, as when driven mechanism is over-running, the formula is as follows:

$$E_r = \frac{1 - f \cot \lambda}{1 + f \tan \lambda} \quad (2)$$

For self-locking worm,

$$\tan \lambda = f \quad (3)$$

The following table gives functions of angles in the most convenient form for worm gear calculations and makes reference to more complete tables unnecessary.

Natural Functions of Angles for Use in Gear Calculations

Deg.	Rad.	sin	csc.	cos	sec	tan	cot	Rad.	Deg.
0	0.0000	0.0000	∞	1.0000	1.0000	0.0000	∞	1.5708	90
1	0.0175	0.0175	57.2987	0.9998	1.0002	0.0175	57.2900	1.5533	89
2	0.0349	0.0349	28.6537	0.9994	1.0006	0.0349	28.6363	1.5359	88
3	0.0524	0.0523	19.1073	0.9986	1.0014	0.0524	19.0811	1.5184	87
4	0.0698	0.0698	14.3356	0.9976	1.0024	0.0699	14.3007	1.5010	86
5	0.0873	0.0872	11.4737	0.9962	1.0038	0.0875	11.4301	1.4835	85
6	0.1047	0.1045	9.5668	0.9945	1.0055	0.1051	9.5144	1.4661	84
7	0.1222	0.1219	8.2055	0.9925	1.0075	0.1228	8.1443	1.4486	83
8	0.1396	0.1392	7.1853	0.9903	1.0098	0.1405	7.1154	1.4312	82
9	0.1571	0.1564	6.3925	0.9877	1.0125	0.1584	6.3138	1.4137	81
10	0.1745	0.1736	5.7588	0.9848	1.0154	0.1763	5.6713	1.3963	80
11	0.1920	0.1908	5.2408	0.9816	1.0187	0.1944	5.1446	1.3788	79
12	0.2094	0.2079	4.8097	0.9781	1.0223	0.2126	4.7046	1.3614	78
13	0.2269	0.2250	4.4454	0.9744	1.0263	0.2309	4.3315	1.3439	77
14	0.2443	0.2419	4.1336	0.9703	1.0306	0.2493	4.0108	1.3265	76
15	0.2618	0.2588	3.8637	0.9659	1.0353	0.2679	3.7321	1.3090	75
16	0.2793	0.2756	3.6280	0.9613	1.0403	0.2867	3.4874	1.2915	74
17	0.2967	0.2924	3.4203	0.9563	1.0457	0.3057	3.2709	1.2741	73
18	0.3142	0.3090	3.2361	0.9511	1.0515	0.3249	3.0777	1.2566	72
19	0.3316	0.3256	3.0716	0.9455	1.0576	0.3443	2.9042	1.2392	71
20	0.3491	0.3420	2.9238	0.9397	1.0642	0.3640	2.7475	1.2217	70
21	0.3665	0.3584	2.7904	0.9336	1.0711	0.3839	2.6051	1.2043	69
22	0.3840	0.3746	2.6695	0.9272	1.0785	0.4040	2.4751	1.1868	68
23	0.4014	0.3907	2.5593	0.9205	1.0864	0.4245	2.3559	1.1694	67
24	0.4189	0.4067	2.4586	0.9135	1.0946	0.4452	2.2460	1.1519	66
25	0.4363	0.4226	2.3662	0.9063	1.1034	0.4663	2.1445	1.1345	65
26	0.4538	0.4384	2.2812	0.8988	1.1126	0.4877	2.0503	1.1170	64
27	0.4712	0.4540	2.2027	0.8910	1.1223	0.5095	1.9626	1.0996	63
28	0.4887	0.4695	2.1301	0.8829	1.1326	0.5317	1.8807	1.0821	62
29	0.5061	0.4848	2.0627	0.8746	1.1434	0.5543	1.8040	1.0647	61
30	0.5236	0.5000	2.0000	0.8660	1.1547	0.5774	1.7321	1.0472	60
31	0.5411	0.5150	1.9416	0.8572	1.1666	0.6009	1.6643	1.0297	59
32	0.5585	0.5299	1.8871	0.8480	1.1792	0.6249	1.6003	1.0123	58
33	0.5760	0.5446	1.8361	0.8387	1.1924	0.6494	1.5399	0.9948	57
34	0.5934	0.5592	1.7883	0.8290	1.2062	0.6745	1.4826	0.9774	56
35	0.6109	0.5736	1.7434	0.8192	1.2208	0.7002	1.4281	0.9599	55
36	0.6283	0.5878	1.7013	0.8090	1.2361	0.7265	1.3784	0.9425	54
37	0.6458	0.6018	1.6616	0.7986	1.2521	0.7536	1.3270	0.9250	53
38	0.6632	0.6157	1.6243	0.7880	1.2690	0.7813	1.2799	0.9076	52
39	0.6807	0.6293	1.5890	0.7771	1.2868	0.8098	1.2349	0.8901	51
40	0.6981	0.6428	1.5557	0.7660	1.3054	0.8391	1.1918	0.8727	50
41	0.7156	0.6561	1.5243	0.7547	1.3250	0.8693	1.1504	0.8552	49
42	0.7330	0.6691	1.4945	0.7431	1.3456	0.9004	1.1106	0.8378	48
43	0.7505	0.6820	1.4663	0.7314	1.3673	0.9325	1.0724	0.8203	47
44	0.7679	0.6947	1.4396	0.7193	1.3902	0.9657	1.0355	0.8029	46
45	0.7854	0.7071	1.4142	0.7071	1.4142	1.0000	1.0000	0.7854	45
Deg.	Rad.	cos	sec	sin	csc	cot	tan	Rad.	Deg.